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BEDROCK AND SURFICIAL GEOLOGY - ROCK AND TILL GEOCHEMISTRY IN THE TROUSERS LAKE AREA, VICTORIA COUNTY, NEW BRUNSWICK

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ABSTRACT

The bedrock and surficial geology of the Trousers Lake area of Victoria County, New Brunswick were mapped in the vicinity of two known base metal occurrences. Bedrock and till samples were chemically analyzed and dispersion patterns outlined.

The mapped area lies on the boundary of two stratigraphic belts. The Tobique-Chaleur Zone, located in the west, is underlain by Devonian volcanic and sedimentary rocks. Felsic volcanic rocks in this zone are host to the Mount Costigan deposit which occurs as a stockwork of veinlets and disseminations of sphalerite and galena within a breccia pipe. The Miramichi zone, located to the east, is underlain by (1) Precambrian granitic gneiss, amphibolite, psammite, pelite, and augen granite, (2) Cambro-Ordovician quartzose sandstone and slate, (3) Ordovician granite, and (4) Devonian gabbro and granite. A lobe of granite extending westward off a large Devonian pluton is host to the Long Lake deposit. The lobe is composed of biotite granite, muscovite-bearing granite and quartz-feldspar porphyry dykes; all contain over one percent normative corundum and were presumably derived by partial melting of an aluminous sedimentary source. The granite lobe was intruded to within 3 to 4 km of the paleosurface in the Early Devonian; over a kilometre of erosion took place before dyke emplacement in the Late Devonian. Trace elements suggest that the muscovite-bearing granite is a water-rich differentiate of the biotite granite, whereas the quartz-feldspar porphyry dykes have a separate origin. Sulphide mineralization occurs as veins of pyrite, sphalerite, chalcopyrite and galena localized along northwest-trending fractures within the granite, quartz-feldspar porphyry and surrounding country rocks. Uranium and molybdenum mineralization is concentrated in breccia zones along the same fracture system near the margin of the muscovite-bearing granite which forms the core of the lobe. Hydrothermal alteration in the mineralized zones has resulted in a large depletion of calcium and sodium and gain of water due to hydrolysis of feldspar in both the granite and dykes.

Over ninety percent of the area is covered by Late Wisconsinan morainal deposits composed of a compact basal till and overlying bouldery ablation till. These deposits vary from less than 1 m to over 20 m thick. Glacial striae and till fabric analyses indicate that ice movement was to the east-southeast. Glaciolacustrine deposits were formed on the eastern part of Long Lake when ice blocked its western outlet to the Tobique River and reversed its drainage direction. Till samples were collected at 174 sites on a regular 1 km grid. Glaciofluvial deposits occurring locally over the ablation till were not sampled since they can contain material transported over great distances. Sulphide pebbles were found in some eskers. B-horizon samples were analyzed for Cu, Pb, Zn, Ag, Mn, Co, Ni, Fe, U, and Mo; C-horizon samples were analyzed for W and Au. Pebble counts on C-horizon samples established that a given pebble lithology increases to a maximum 1 to 2 km down ice from its bedrock boundary. The bedrock source of geochemical anomalies should, therefore, be found at approximately this distance up ice.

Sulphide mineralization of the Long Lake deposit is the source of the high Pb, Zn, Cu, Mn, and Ag anomalies to the southeast of Cheaver Lakes. A separate U anomaly located farther southeast reflects the known association of U mineralization with the contact of a muscovite-bearing granite in the same deposit. A Ag anomaly on the eastern flank of Costigan Mountains is related to the Mount Costigan breccia pipe mineralization. The small displacement of this anomaly may be due to the resistance of the silicified volcanic rocks to erosion or the lee side of the mountain may have been an area of deposition rather than erosion.

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BEDROCK AND SURFICIAL GEOLOGY - ROCK AND TILL GEOCHEMISTRY IN THE TROUSERS LAKE AREA, VICTORIA COUNTY, NEW BRUNSWICK

INTRODUCTION

The Trousers Lake area is located in north-central New Brunswick between 46°47', 47°07'N latitude and 66°48', 67°04'W longitude (Figure 1). It lies largely in eastern Victoria County, but includes a small portion of extreme western Northumberland County. Over the past 20 years, the area has been investigated for potential economic mineralization following the discovery of geochemical anomalies. Subsequent trenching and drilling has revealed base metal and uranium mineralization associated with Devonian volcanic and granitic rocks. During the summer of 1983, a till sampling program was carried out in the vicinity of these known mineral occurrences in order to test their geochemical response. Both the bedrock and surficial geology were mapped to obtain a solid data base for the till sampling and interpretation of the geochemical results.

Figure 1. Stratigraphic zones of New Brunswick showing location of Trousers Lake area.

The mapped area lies at the junction of four 1:50,000 N.T.S. sheets (Plaster Rock, 21 J/14; Tuadook Lake, 21 J/15; Riley Brook, 21 O/3; and Serpentine Lake, 21 O/2) and covers an area of some 375 km^2. It straddles the boundary of two stratigraphic belts: the Tobique-Chaleur Zone in the west, underlain by Devonian volcanic and sedimentary rocks, and the Miramichi Zone in the east, underlain by Precambrian gneiss and Cambro-Ordovician metasedimentary rocks intruded by plutonic rocks of various ages (Figure 1).

Access to the area is by well maintained timber haulage roads off the Plaster Rock-Renous Highway. Existing one inch to one-quarter mile (1:15,840) maps (Crouse, 1977a, b; Irrinki, 1977a, b) were used to locate outcrops, most of which were visited during the present 1:20,000 scale survey. Till sampling was concentrated along the western margin of a large Devonian granitic intrusion and its contacts between Serpentine Lake in the north and Costigan Mountains in the south. Samples were collected on a regular 1 km grid over about 180 km^2. B-horizon samples were collected and analyzed for Pb, Zn, Ag, Cu, Fe, Ni, Co, Mn, Mo, and U, while C-horizon samples were taken for W and Au analysis and pebble lithology study. Site descriptions were made so that the geological, geomorphological and geochemical data could be combined to form a complete picture of the surficial geology in relation to the geochemistry of tills and bedrock mineralization.

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PHYSIOGRAPHY

The area under investigation is part of the Miramichi Highlands of the Appalachian Region of Canada (Rampton et al., 1984). The highest points in the area are the Costigan Mountains with a maximum elevation of 671 m (Figure 2; Plate 84-22A); Mount Carleton, 45 km to the north, is the highest point in the province at 820 m. Maximum local relief is 275 m but generally averages 100 m. Rounded hills on granitic bedrock produce an undulating topography, whereas areas underlain by volcanic rocks have a more rugged relief.

The western part of the area drains towards the

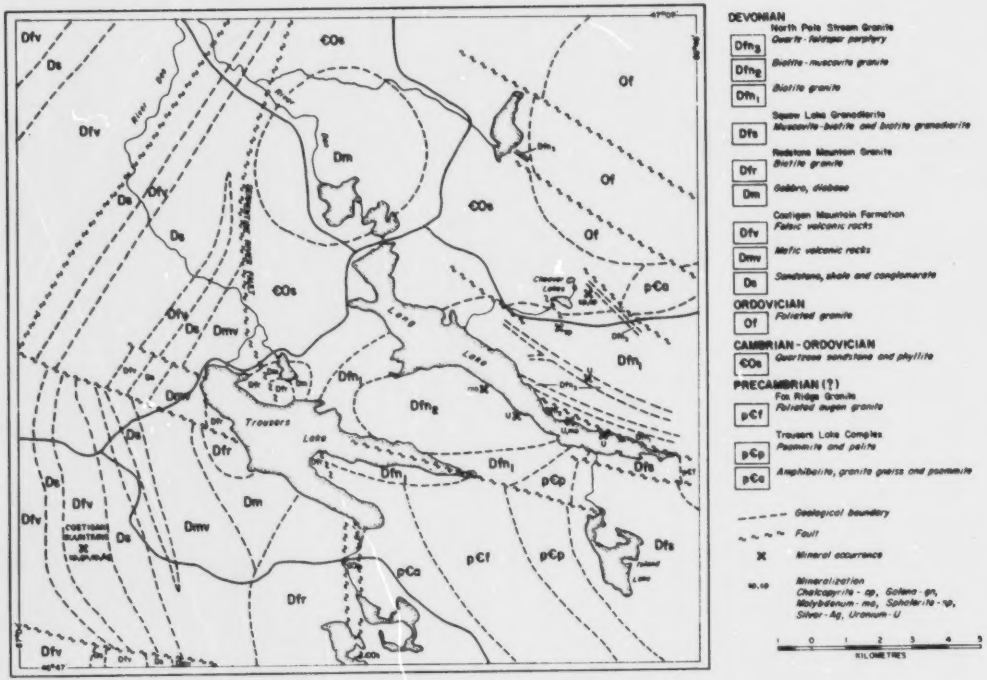

Figure 2. Bedrock geology of Trousers Lake area.

northwest and west into the Saint John River via the Tobique River (the River Dee and River Don are tributaries of the Right Hand Branch Tobique River), while the eastern part drains towards the east into the Southwest Miramichi River. Abundant lakes and swamps mark the deranged dendritic drainage of the area. Most of the area is covered by glacial drift that has smoothened the original bedrock relief.

PREVIOUS WORK

Gesner (1843) recognized that the boundary separating Silurian strata from an anticlinal ridge of Cambrian greywacke and slate to the east trended diagonally across New Brunswick and passed near the headwaters of the Tobique River. This boundary corresponds with that between the Tobique-Chaleur Zone and Miramichi Zone shown in Figure 1.

Bailey (1864) observed felsic volcanic rocks along the upper parts of the Tobique River. Bailey did not speculate on the age of these rocks which are now known to be Devonian (Figure 2). Hind (1865) recorded the presence of granite boulders on Long Lake and Trousers Lake and noted an outcrop of chloritic rock (Cambro-Ordovician phyllite) to the south on Mud Lake.

Robb (1870) and Ells (1881) briefly described the rocks to the north of the report area along the Tobique River and its tributary, the Serpentine River. Ells (1881) assigned much of the massive volcanic rocks (now known to belong to the Devonian of the Tobique-Chaleur Zone), and schistose volcanic and sedimentary rocks (now assigned to the Ordovician and Cambrian of the Miramichi Zone) to the Precambrian because of their similarity to Hadrynian volcanics of southern New Brunswick.

Bailey and McInnes (1887), following Ells, placed gneissic granite and quartzite of the Miramichi Zone along the Serpentine River in the Precambrian. They also noted boulders of fine-grained, red syenite and coarse-grained Devonian granite along Trousers Lake and Long Lake, respectively. McInnes discovered Devonian fossils in calcareous sandstone farther west along Right Hand Branch Tobique River (Campbell River), but continued to include associated volcanics in the Precambrian (Bailey and McInnes, 1887). Bailey (1904, 1906) in a re-examination of the Tobique area concluded that the massive volcanic rocks were Silurian (actually Devonian of the Tobique-Chaleur Zone), but did not preclude the occurrence of Precambrian rocks farther east in the Miramichi Zone.

Rose (1942) studied the regional distribution of the granitic rocks in central New Brunswick. He did not distinguish between deformed plutons of Ordovician or older age and massive plutons of Devonian age.

Skinner (1975, 1982) mapped the southern portion of the Trousers Lake on a 1:50,000 scale. He considered amphibolite and paragneiss of the Miramichi Zone be be equivalent to the lower part of the Tetagouche Group and placed them in the Cambrian to early Ordovician. He assigned the foliated granite to be

Ordovician or Silurian. Rast et al. (1976) suggested that the amphibolite and paragneiss might be Precambrian. St. Peter (1978) subdivided the interbedded Devonian volcanic and sedimentary rocks of the Tobique-Chaleur Zone into formations.

The surficial geology has previously been described by Chalmers (1901), Langmaid et al. (1976), Rampton and Paradis (1981), Gauthier (1982a, b), and Lavergne and Hunter (1982).

BEDROCK GEOLOGY

STRATIGRAPHY

Precambrian(?):

Trousers Lake Complex (Units pЄa, pЄp): A diverse assemblage of amphibolite, granitic gneiss, psammite and pelite exposed between Trousers Lake in the north and Little Indian Lake just to the south of the map boundary is herein referred to as the Trousers Lake Complex (Figure 2, Plate 84-22A). An exposure of interlayered amphibolite and granitic gneiss on the southeastern tip of the right hand leg of Trousers Lake is designated as the type section (Figures 3, 4).

Unit pЄa is characterized by its abundance of dark greyish green amphibolite of which two varieties can be distinguished. The first type is medium-grained (grain size 0.3 mm), relatively massive, and occurs as layers typically about 0.5 m thick in association with granitic gneiss (Figure 4). This amphibolite is composed chiefly of green hornblende with a weak preferred orientation surrounding dispersed grains of untwinned plagioclase. Thin (0.5 to 5 cm thick) quartzofeldspathic layers containing biotite and sparse porphyroblasts of plagioclase occur within the amphibolite (Figure 5). Some thick, grey, apparently psammitic layers exposed on Trousers Lake contain porphyroblasts of hornblende.

Figure 3. Trousers Lake looking northwest from the type area of the Trousers Lake Complex.

Figure 4. Interlayered granitic gneiss and amphibolite of the Trousers Lake Complex.

The second type of amphibolite is thin-banded, containing schistose layers of green hornblende separated by less abundant, thinner layers (0.5 cm thick) of untwinned, granular plagioclase with a grain size of 0.1 mm. The steep layering is transposed along a later crenulation foliation resulting in the creation of small interfolial folds outlined by the light grey plagioclase-rich layers.

Thin-bedded amphibolite on the road, 800 m south of the type-section, is interbedded with up to 50 percent dark grey, schistose psammitic sedimentary rocks. The presence of flakes of mica on its broken cleavage surfaces makes the psammite readily distinguishable from the amphibolite. The muscovite and biotite defining the schistosity are crenulated by a fabric along which no mineral growth has occurred. No primary sedimentary features are recognizable in these rocks presumably because of extensive transposition during deformation.

Similar psammite located along the road 600 m east of the type-section exhibits folds plunging 40° to the south (Figure 6). Only one layer of amphibolite about 5 cm thick is present in the outcrop. The psammite is extensively recrystallized and contains abundant cordierite suggesting that it is in close proximity to the unexposed contact of the Devonian granite pluton known to occur farther north.

Fine-grained, pink granitic gneiss interbanded with the more massive amphibolite occurs in layers typically from 15 cm to 1 m thick (Figure 7). The gneissosity, defined by elongated quartz and feldspar grains with an average grain size of 0.1 mm, is flattened around ragged microcline augen up to 2 mm in diameter. Concentrations of sparse accessory minerals including biotite, chlorite, sphene and opaques accentuate the foliation. Sparsity of outcrop makes it impossible to determine the number and distribution of individual layers of gneiss, but two separate narrow belts containing abundant gneiss appear to be present. The first belt passes through the type section and is separated by interlayered psammite and thin-banded amphibolite from the second belt which occurs 500 m farther east. The gneissic belts trend

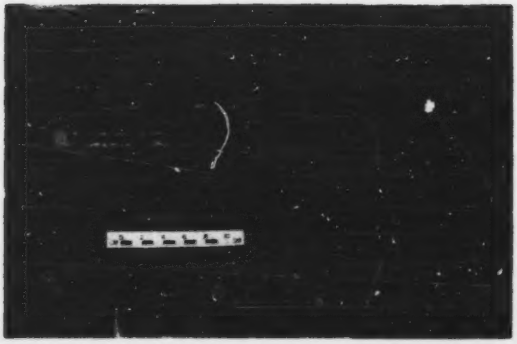

Figure 5. Amphibolite containing thin quartzo-feldspathic bands within Trousers Lake Complex.

Figure 6. Folded psammite within the Trousers Lake Complex.

southward and then southeastward to the haulage road running north of Little Indian Lake just beyond the southern limit of the map area.

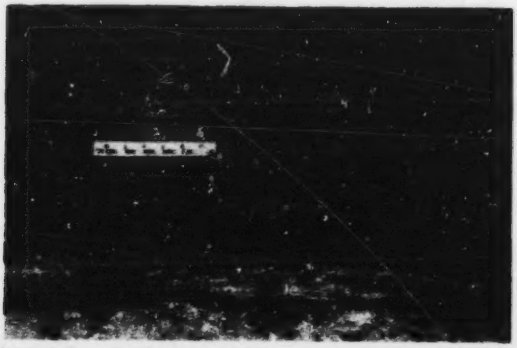

Figure 7. Gneissose structure in granitic gneiss of Trousers Lake Complex.

Exposures which may correlate with Unit pEa occur 2 km east of Cheaver Lakes to the northeast of Long Lake. Rocks in this area vary from medium-grained, equigranular, dark grey hornblende-bearing granodioritic gneiss to medium grey biotite-bearing granitic gneiss containing microcline augen up to 4 mm in diameter. Veins of the granitic gneiss inject both a light grey biotitiferous psammite and dark grey amphibolite containing euhedral, sericitized plagioclase phenocrysts about 4 mm in length set in a matrix of green hornblende and twinned andesine. The gneissic foliation in these rocks is generally gently dipping.

Psammite and interbedded pelite (Unit pEp) extend along the eastern border of the map area from just east of Island Lake northward to Long Lake. These rocks are included as part of the Trousers Lake Complex because of their similarity to the psammitic rocks found interbedded with amphibolite farther west. Near the southwestern end of Island Lake, mobilization of psammite resulting in brecciation of interbedded cordierite-bearing pelite layers is produced by contact metamorphism associated with the Squaw Lake Granodiorite (Figure 8).

The Trousers Lake Complex of the type area is faulted against probable Cambro-Ordovician metasedimentary rocks and Devonian volcanics to the west. The fault zone extends south from Trousers Lake through Mud Lake to Gulquac Lake. Amphibolite and psammite near this zone contain fractures filled with prehnite, epidote and chlorite. The relationship of the gneissic rocks to the north in the Cheaver Lakes area to Cambro-Ordovician rocks found farther west is not known because of poor exposure in the area.

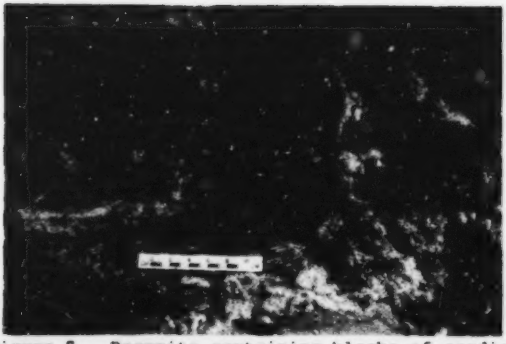

Figure 8. Psammite containing blocks of cordierite-bearing pelite.

Precambrian rocks have been thought to exist in central New Brunswick since mapping began in the mid-1800's. Volcanic rocks were commonly regarded as Precambrian because of their similarity to those of the Coldbrook Group of southern New Brunswick. Later fossil discoveries proved the former were either part of the Ordovician Tetagouche Group or Devonian Tobique Group. Consequently, Skinner (1975) considered the high grade regional metamorphic rocks of the west-central Miramichi Zone to be equivalent to the lower part of the Tetagouche Group found farther east, and he therefore, assigned a Cambrian to Early Ordovician age to them. However, Rast et al. (1976) contended that the metamorphic rocks were Precambrian by comparison with supposed Precambrian gneisses of eastern Newfoundland. Fyffe and Cormier (1979) presented age-dating evidence which showed that the metamorphic terrane had cooled substantially before intrusion of Early Devonian granite.

The relationship of the Trousers Lake Complex to the greenschist facies sedimentary rocks of the lower Tetagouche Group found farther east remains unresolved. The contact may be a metamorphic gradation as implied by Skinner (1975) or it may be a remobilized unconformity as suggested by Rast et al. (1976). A Precambrian age is preferred for the Trousers Lake Complex in this report because its unique lithology (granitic gneiss and amphibolite of Unit pЄa) cannot easily be correlated with lesser metamorphosed rocks of the Tetagouche Group. Many of the rocks included in the migmatite complex of Fyffe (1982a) are probable correlatives of the Trousers Lake Complex.

Fox Ridge Granite (Unit pЄf): The type section of the Fox Ridge Granite (Crouse, 1978) is on the haulage road that cuts through Fox Ridge, 2 km southeast of Costigan Lake in the southeastern part of the map area. The granite forms an elongate body that trends northwestward from the type area to the area east of Trousers Lake.

The Fox Ridge Granite is characterized by pink, ovoid, alkali feldspar augen up to 2 cm in diameter that commonly

exhibit rapakivi mantling. The foliation in the cataclastically deformed granitic matrix is accentuated by recrystallized biotite and muscovite (Figure 9). Light pink aplite dykes up to 15 cm in width have intruded the augen granite parallel to the foliation (Figure 10).

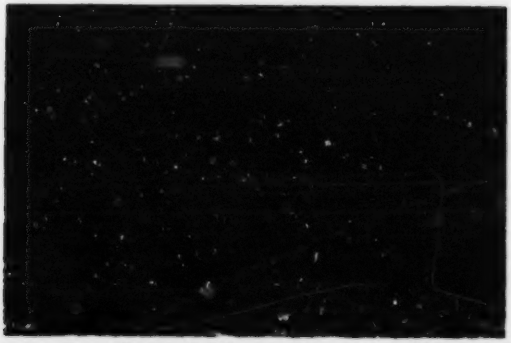

Figure 9. Alkali feldspar augen in foliated Fox Ridge Granite.

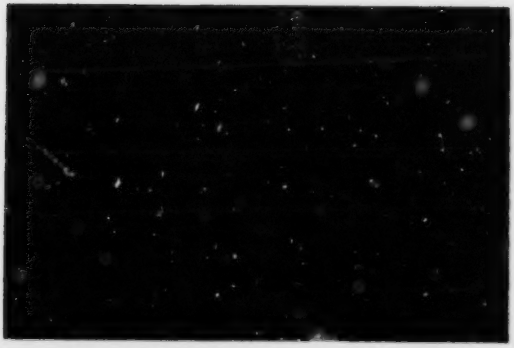

Figure 10. Aplite dykes in Fox Ridge Granite.

TABLE 1

RADIOMETRIC DATA - FOX RIDGE GRANITE

SAMPLE NO.	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$
B	270	25.8	30.9	0.8980
F	237	35.5	19.6	0.8264
E	196	64.1	8.90	0.7636
C	205	87.8	6.75	0.7475
D	193	96.4	5.80	0.7428
A	199	102	5.68	0.7419

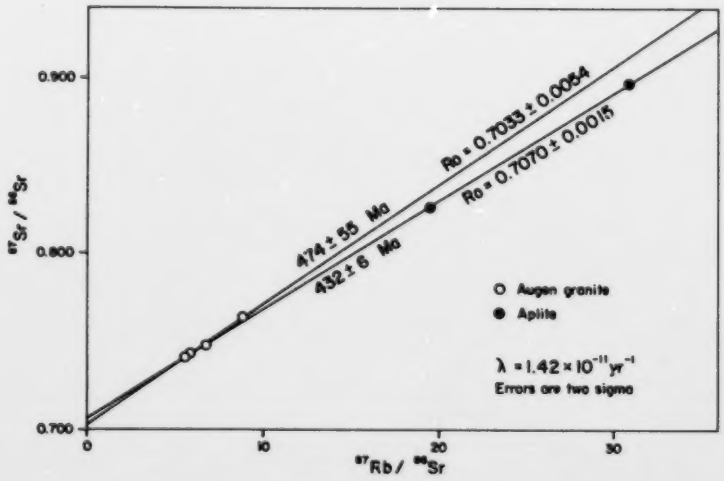

Figure 11. Rubidium-strontium isochron for the Fox Ridge Granite.

The Fox Ridge Granite is tentatively assigned to the Precambrian because it does not intrude rocks younger than the Trousers Lake Complex. The contacts of the granite with the complex is not exposed but appear to be concordant. An attempt was made to date the Fox Ridge Granite by the rubidium-strontium method. Six samples were analyzed, four from the augen granite and two from the invading aplite (Table I). These yielded an age of 432±6 Ma with an initial ratio of 0.7070±0.0015 (Figure 11). This Silurian age seems much too young given the highly deformed nature of the granite. The slope of the isochron is largely controlled by the aplite samples and regression excluding these two points gives an early Ordovician age of 474±55 Ma and an initial ratio of 0.7033±0.0054. Early Ordovician ages have been obtained from other deformed granites in central New Brunswick (Fyffe et al., 1977; Poole, 1980). It is, therefore, possible that the division of deformed granites into two age groups (Ordovician and Precambrian) based on the degree of deformation and inferred ages of intruded rocks is incorrect (see Unit Of below).

Cambrian and Ordovician:

Quartzose sandstone and phyllite (Unit €Os): Interbedded light grey quartzose sandstone and dark grey phyllite underlie the northern part of the area between River Dee in the west and Cheaver Lakes in the east. Light green sandstone and maroon phyllite is found within the same unit 2.4 km west of Square Lake and is abundant north of the map boundary in the vicinity of Serpentine Lake.

Unit €Os is regionally metamorphosed to greenschist facies. The sandstone, which preserves a relict clastic texture outside contact metamorphic aureoles, is composed mainly of quartz with an average grain size of 0.15 mm and minor sericite, feldspar, chlorite, tourmaline, zircon and opaques. Phyllite is finer grained and contains abundant sericite. Within about 2 km of major Devonian plutons incipient biotite appears and within 1.5 km, cordierite porphyroblasts up to 5 mm in length develop with a concomitant grain size increase of quartz and mica to about 0.3 mm.

Folds within outcrops on the River Dee plunge moderately south, whereas those on the southern end of Britt Brook Lake plunge gently north.

A fault breccia about 1 m wide is exposed 2.4 km west of Square Lake and contains angular fragments of quartzose sandstone and phyllite. The breccia separates rocks of Unit €Os exposed immediately to the east from Devonian conglomerate and sandstone exposed a short distance to the west. This fault is, herein, referred to as the Serpentine River Fault after exposures found on the Serpentine River some 20 km north of the map area.

An exposure of laminated sandstone on the road 800 m south of Trousers Lake and abundant float along the west side of Mud Lake suggest that a fault slice of Unit €Os is preserved between Precambrian(?) and Devonian rocks along the southern extension of the Serpentine River Fault. A large exposure along the fault trace near the outlet from Mud Lake consists of a very fine-grained phyllonite possessing a steep north-trending folia-

tion. The comminuted matrix of the phyllonite is overgrown by small porphyroblasts of chlorite.

Unit €Os is assigned to the Cambro-Ordovician based on its lithologic similarity to the Cambrian Grand Pitch Formation of Maine (Neuman, 1967), and to rocks in the Woodstock area of south-central New Brunswick which contain early Ordovician graptolites (Fyffe et al., 1983).

Metagranite (Unit Of): Pink, equigranular, medium-grained, weakly foliated metagranite, exposed 3 km northeast of Cheaver Lakes, can be traced by float northwestward to Britt Brook Lake. From there, it continues north of the map boundary to Serpentine River where outcrops near the confluence of Bubar Brook contain abundant roof pendants of Unit €Os. The granite has been extensively recrystallized to a granular mosaic composed of ragged perthite and plagioclase crystals up to 4 mm in size set in a finer matrix of quartz and biotite.

Similar deformed granites in central New Brunswick have yielded Early Ordovician rubidium-strontium whole rock ages (Fyffe et al., 1977; Poole, 1980) which are consistent with the observed intrusive relationship with Unit €Os on the Serpentine River.

Devonian:

Costigan Mountain Formation (Units Ds, Dmv, Dfv): St. Peter, working to the south of the Trousers Lake area, mapped and named the Costigan Mountain Formation. A full description of the formation is given in St. Peter (1978, 1982).

The Costigan Mountain Formation occurs on the western margin of the Trousers Lake area where it is faulted against older rocks to the east along the Serpentine River Fault. Bedding in the southern part of the formation trends northerly to northwesterly, but in the northern part, trends northeasterly. This change in trend apparently occurs across a linear extending east-southeastward from North Branch Gulquac River to Trousers Lake. The existance of a fault along this linear was confirmed by a traverse between Colters Mountain and Spruce Mountain. An exposure of sheared slate intruded by diabase along an old logging road in this area is directly on strike with a large outcrop of felsic volcanics located on a hill a short distance to the north.

The lowest part of the Costigan Mountain Formation preserved in the Trousers Lake area (Plate 84-22A) is a west-dipping sequence of greyish green mafic volcanic rocks (Unit Dmv) intercalated with less abundant sedimentary rocks composed of interbedded grey slate, sandstone and minor conglomerate (Unit Ds). Buff, generally flow-layered rhyolite (Unit Dfv), also containing interbeds of Unit Ds, occurs above the mafic volcanic sequence. The rhyolite contains small, sparse phenocrysts of feldspar set in a felsitic matrix that locally preserves a perlitic texture. The interbedded sedimentary rocks contain several Early Devonian fossil occurrences (Bailey and McInnes, 1887; Crouse, 1977a; Skinner, 1982).

Vent breccia, exposed in trenches a short distance to

the scutheast of the abandoned fire tower located on the highest point of Costigan Mountains (Plate 84-28A), occurs as an irregular circular zone several metres in diameter largely within a unit of dark grey chloritic crystal tuff (Unit Dct). The breccia comprises blocks up to 20 cm in diameter of the crystal tuff veined by buff felsite (Figures 12, 13). Flow-layering in many of the blocks trends easterly indicating that the blocks have been rotated from the usual north-northeasterly strike as exhibited by layering in volcanics to the west of Falls Brook. The volcanic blocks contain abundant feldspar and quartz crystals about 1 mm in size set in a matrix of flattened shards partially replaced by chlorite. The veining material consists of a fine-grained mosaic of quartz and minor feldspar. Small irregular-shaped fragments and blocks of siltstone are abundant in the basal unbrecciated portion of the crystal tuff unit.

Figure 12. Trenches on eastern flank of Costigan Mountains.

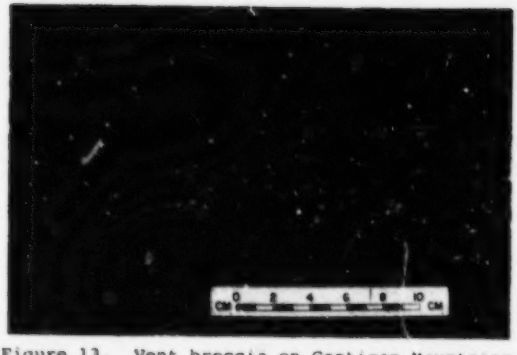

Figure 13. Vent breccia on Costigan Mountains (Sample Site 4).

Light grey, sugary-textured felsic lapilli tuff (Unit Dlt), which occurs in the western portion of the trenches, stratigraphically overlies the crystal tuff. This obviously silicified lapilli tuff contains phenocrysts of alkali feldspar and very fine-grained, dark grey, chloritized siltstone(?) fragments (Figure 14). A potassium-argon determination of this rock (Sample No. 3, Plates 84-22A, 84-28A) by Teledyne Isotopes yielded an age of 373±19 Ma.

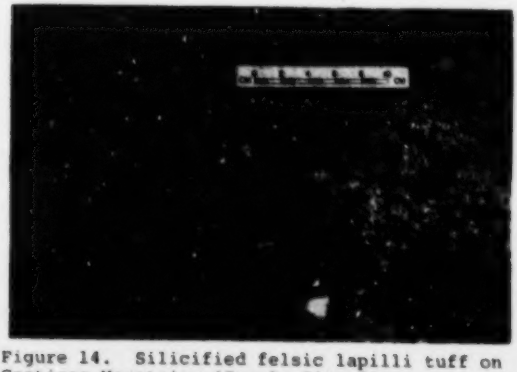

Figure 14. Silicified felsic lapilli tuff on Costigan Mountains (Sample Site 3).

Rubble of felsic lapilli tuff at the base of the dismantled fire tower does not have the sugary silicified texture found in the lapilli tuff in the trenches farther to the southeast. This less altered tuff contains abundant small fragments of felsic volcanic rocks and alkali feldspar set in a felsitic matrix partially replaced by chlorite. A massive to weakly flow-banded, buff-coloured felsic volcanic flow (Unit Dff) containing pink feldspar phenocrysts is exposed in a trench southwest of the fire tower and must, therefore, overlie the lapilli tuff.

Gabbro and Diabase (Unit Dm): A circular stock with an area of 20 km^2, located off the northwestern end of Long Lake, is composed of olivine gabbro. The gabbro contains phenocrysts of olivine, clinopyroxene and plagioclase about 5 mm in size set in a matrix with a grain size of about 1 mm. The matrix possesses a diabasic texture formed by plagioclase and interstitial actinolite and biotite. Abundant sedimentary xenoliths are found along the margin of the gabbro on Clark Mountain and on the road just south of Square Lake. Along the same road, a dyke of red felsite can be observed to have intruded the gabbro.

A separate body of gabbro trends along the trace of the Serpentine River Fault from Gulquac Lake northward across the western end of Trousers Lake to Blind Lake. The gabbro has a subophitic texture formed of plagioclase laths about 2 mm in length partially enclosed in larger orthopyroxene crystals which are altered to mosaics of actinolite around their edges. Cordierite-rich xenoliths within the gabbro east of Blind Lake prove that it was intrusive into Cambro-Ordovician sedimentary rocks along its eastern margin. Its western contact with the Devonian Costigan Mountain Formation was not observed but is undoubtably intrusive as the associated Redstone Mountain Granite (Unit Dfr) contains mafic volcanic xenoliths of Unit Dmv on the southwest side of Trousers Lake.

Diabase dykes are most common within the Costigan Mountain Formation, but one of the largest has intruded Cambro-Ordovician sedimentary rocks exposed along the road on the western end of Long Lake. This dyke, which is about 10 m wide, contains sparse, slender, aligned plagioclase phenocrysts about 1 mm in length set in a very fine-grained matrix of plagioclase, actinolite and minor biotite. It strikes at 85° with a 70° dip to the north and may be a westward continuation of the dyke located on the hill 2 km northwest of the mouth of Cronin Brook.

A 2 m wide dyke, exposed on the road south of Trousers Lake, also strikes to the east through the Redstone Mountain Granite. The dyke contains clusters of tabular plagioclase phenocrysts about 1 mm in length that does not exhibit a flow alignment. Actinolite occurs as both porphyroblasts and small crystals in the groundmass. Diabase dykes, intruding probable Cambro-Ordovician sedimentary rocks along the same road 1 km further east, strike to the north.

Redstone Mountain Granite (Unit Dfr): The Redstone Mountain Granite (Crouse, 1978) is an elongate pluton which can be traced northward to the western end of Trousers Lake from its type locality on Redstone Mountain some 15 km to the south. It is a pale pink biotite granite characterized by the presence of

slightly larger euhedral plagioclase laths and quartz crystals set in a medium-grained matrix of quartz and anhedral alkali feldspar generally exhibiting granophyric intergrowth (Figure 15). Hornblende is present locally in the type area. Allanite is a common accessory mineral. Many of the large biotite blades are replaced by mosaics of small biotite crystals. These new biotites have grown over kink bands in the original biotite and over epidote-filled fractures. The intensity of biotite recrystallization diminishes toward the southwest and is not observable in samples from just east of Clark Lake. This suggests that the recrystallization is due to contact effects of the nearby North Pole Stream Granite (Unit Dfn) exposed just to the northeast of Trousers Lake.

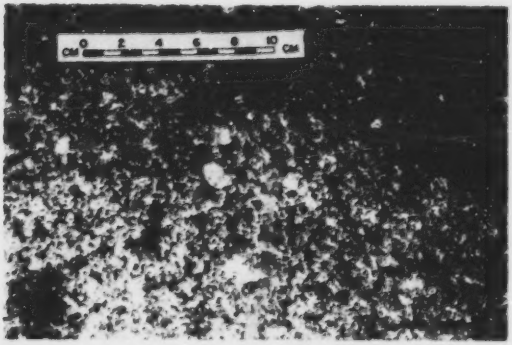

Figure 15. Redstone Mountain Granite (Sample Site 5).

The Redstone Mountain Granite contains abundant blocks of the surrounding gabbro; a few xenoliths of mafic volcanic rocks are present southwest of Trousers Lake. Narrow dykes of dark pink microgranite have intruded medium-grained granite in exposures along the road south of Trousers Lake. Aplite dykes, 1 cm wide, trend 100° in granite outcrop on the southwest shore of the lake. Quartz-feldspar porphyry dykes have intruded gabbro on the brook draining Yellow Lakes.

The granite exposed on an island at the northwestern end of Trousers Lake possesses narrow, north-trending, steep-dipping zones of very fine-grained, thin, alternating light pink and dark grey bands. This ultramylonite presumably developed during movement on the Serpentine River Fault. Wider-spaced, northeast-trending breccia zones displace the ultramylonitic fabric. Other deformational features elsewhere in the Redstone Mountain Granite noted previously (kinked biotite, epidote-filled fractures) are also likely related to this fault movement which must then have largely occurred prior to emplacement of the North Pole Stream Granite.

A nine-point rubidium-strontium whole-rock isochron

from the Redstone Mountain anite yielded an age of 409±25 Ma which is compatible with its intrusive relationship to the Lower Devonian Costigan Mountain Formation (Fyffe and Cormier, 1979).

Squaw Lake Granodiorite (Unit Dfs): The Squaw Lake Granodiorite, which occupies the southeastern portion of the map area, is known to extend from Squaw Lake eastward for 3 km beyond the map boundary (Fyffe, 1979). It was originally included as a distinct northern phase of the North Dungarvon River Granite (Irrinki, 1978, Fyffe et al., 1981) but, following Skinner (1975), is considered here as a separate pluton. Exposures on the road along the east side of Island Lake are designated as the type locality.

The granodiorite is medium-grained, grey, equigranular, and contains abundant xenoliths of psammite and rare amphibolite. Typically, the unit is composed of quartz, euhedral plagioclase laths about 4 mm in length, and less abundant subhedral orthoclase perthite crystals about 5 mm long enclosing small plagioclase laths. Biotite and muscovite, which comprise about 5 percent of the rock, occur as separate blades and as oval clusters that appear to be cordierite pseudomorphs.

On the brook draining Island Lake, 50 m upstream from its outlet into Long Lake, light grey granodiorite contains about 10 percent, commonly kinked biotite and no muscovite. Plagioclase laths are smaller and more strongly zoned than those around Island Lake, and also exhibit kinked twin lamellae. Another 100 m up the brook, the rock is stained red and contains narrow shear zones trending northwestward. A strong, west-northwest-trending linear, underlain by swampy ground, occurs 1 km west of the brook about 200 m south of Long Lake. The above evidence suggests that a parallel fault may underlie Long Lake, separating the northern margin of the Squaw Lake Granodiorite from the North Pole Stream Granite exposed on the opposite shore. This fault has been confirmed by diamond drilling (see below).

North Pole Stream Granite (Unit Dfn): The granite underlying the area surrounding Long Lake is a western lobe of a pluton, 800 km^2 in area, referred to as the North Pole Stream Granite (Crouse, 1979). A ten-point, whole-rock rubidium-strontium isochron obtained from the eastern part of the pluton yielded an age of 378±7 Ma (Fyffe, 1982b). A potassium-argon determination on biotite from granite in a drillhole on the northern margin of the lobe, about 1 km south of Cheaver Lakes gave an age of 391±14 Ma (Hauseux, 1980), which agrees with the Rb-Sr age within the limits of error.

The main phase of the North Pole Stream Granite in the Long Lake area is composed of a coarse-grained, greyish pink, equigranular, biotite granite (Unit Dfn_1) containing equal proportions of quartz, alkali feldspar, and plagioclase (Figure 16). Some of the feldspars are up to 1 cm in length but average around 4 mm. The alkali feldspar is an orthoclase perthite containing domains of microcline indicated by grid twinning. Plagioclase is dusted with sericite and lesser epidote. Biotite which forms 1 or 2 percent of the rock is partially altered to chlorite. Small grains of biotite and plagioclase are enclosed in alkali feldspar. Many drillholes in the Long Lake area contain a biotite granite veined by slightly more leucocratic biotite granite (Hauseux, 1981b, 1982).

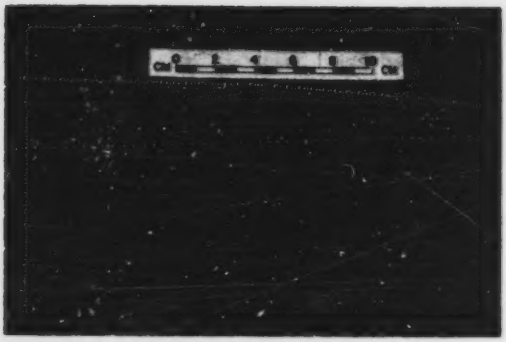

Figure 16. Texture of biotite granite (just east of Sample Site 14).

Granite of the main phase exposed along Cronin Brook on the northern margin of the pluton is pinker, finer grained (2 mm grain size), and contains blades of muscovite in addition to biotite. The intrusive contact with Cambro-Ordovician sedimentary rocks is exposed on the brook just below the outlet of Cheaver Lakes. The contact is abrupt with a few granite veins extending a short distance into the country rocks. Granite veins also occur elsewhere farther north of the contact where they have concordantly intruded the country rocks (Figure 17).

Figure 17. Granite veins east of Cheaver Lakes (near Sample Site 13).

At the bridge over Cronin Brook, the finer grained granite can be observed in fault contact with cordierite-bearing sedimentary rocks to the northest. Muscovite and biotite in the granite contain kink banding related to deformation along the fault. The sheared contact trends 130° and dips 80° southwest (Figures 18, 19).

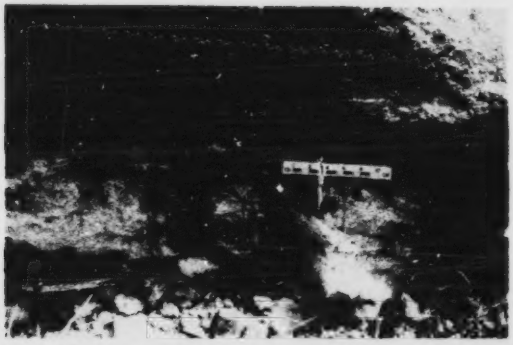

Figure 18. Sheared contact between granite (above scale) and sedimentary rocks (below scale).

Figure 19. Close-up of sheared contact from Figure 18 (Sample Site 9).

Most granite exposures exhibit a steep, orthogonal joint pattern with sets trending near 120° and 30° respectively. Shearing along the southeast-trending set has apparently produced zones of weakness in the granite that are easily eroded and, thereby, control the shape of Long Lake and Trousers Lake. A mylonite zone with an apparent width of 33 m was intersected in a drillhole on the southeastern end of Long Lake (Hauseux, 1982). Narrow alteration zones containing sulphide mineralization occur locally within the southeast-trending fracture system. A subhorizontal joint set along which exfoliation has taken place can be seen in some of the exploration trenches (Figure 20).

Figure 20. Exfoliated biotite granite (Sample Site 4).

A lensoid body of medium-grained, light grey to light pink, equigranular granite (Unit Dfn_2) occurs between Long Lake and Trousers Lake within the main phase of the North Pole Stream pluton. The granite has a grain size of 1.5 mm and contains between 3 to 5 percent combined muscovite and biotite which are present in nearly equal proportions. The micaceous minerals occur both as discrete, generally kinked blades and as sparse clusters up to 1 cm across that appear to be remnants of digested sedimentary xenoliths. A potassium-argon whole-rock determination by Teledyne Isotopes on Sample No. 2 (Plate 84-22A) gave an age of 355±18 Ma which would represent a minimum or cooling age for the granite. Drillholes on Long Lake have intersected coarser grained biotite-muscovite granite and minor pegmatite as well as the finer grained variety; veins of the muscovite-bearing granite can be seen to cut biotite granite (Unit Dfn_1) in the drill core. A rubidium-strontium determination on mineral separates from muscovite granite in one of the drillholes yielded an age of 408 Ma (Hauseux, 1982) which presumably represents the time of crystallization. Its age does not appear to be significantly different from the biotite granite.

Similar medium-grained, muscovite-bearing granite has been mapped by Crouse (1979) just west of Mitchell Lake, about 7 km east of the map boundary, but another stock shown by him adjacent to the map border, just north of Cleaver Lake, is actually biotite granite of the main phase.

Blocky float along both shores at the southeastern end of Long Lake consists of light greyish pink granite breccia from which anomalous scintillometer readings were obtained (Table 2). The limited areal distribution of the float suggests that it is representative of the underlying bedrock. The breccia is sugary-textured as a result of comminution and silicification. Open cavities up to 5 mm in diameter contain quartz crystals and less commonly, pyrite. The quartz crystals are locally coated with hematite giving them a dark maroon colour. The breccia is composed of granite fragments several centimetres in diameter separated by fractures filled with fine-grained granulated and recrystallized quartz. The fragments contain quartz, orthoclase partially replaced by irregular patches of quartz, lesser plagioclase almost completely altered to yellowish green sericite, and blades of muscovite. The average grain size in the fragments is about 4 mm in contrast to the 1.5 mm grain size of biotite-muscovite granite exposed inland to the west. The granite breccia is, therefore, interpreted to have been a water-rich fraction of Unit Dfn_2. Brecciation apparently occurred during release of silica-rich hydrothermal fluid into the fracture system passing through the southeastern portion of Long Lake.

A small body of dark pink microgranite located on the hill north of Cronin Brook along the northern margin of the North Pole Stream pluton is also included in Unit Dfn_2 although it is much finer grained. The microgranite contains sparse phenocrysts of plagioclase and quartz, about 1.5 mm in size, set in a very fine-grained quartzofeldspathic matrix. Muscovite, chlorite, and opaques make up less than 1 percent of the rock.

Quartz-feldspar porphyry dykes (Unit Dfn_3) have intruded the main phase of the North Pole Stream pluton along the northern side of Long Lake. Boulders of similar porphyry are abundant off the southwestern end of Britt Brook Lake to the north of the pluton. The southeasterly trend of the dykes coincide with the orientation of a prominent joint set. The dykes appear to occur in swarms although their exact number and thickness could not be determined because of poor exposure.

The porphyry exposed on the brook draining into the east end of Long Lake is dark pink and contains miarolitic cavities (Sample No. 17). Phenocrysts of plagioclase, quartz, orthoclase and minor biotite (all about 2 mm in size) are set in a fine-grained quartzofeldspathic matrix which constitutes about 50 percent of the rock. Plagioclase phenocrysts occur as clusters of intergrown laths that are dusted with sericite. Quartz phenocrysts also tend to be clustered and have corroded edges. Some of the orthoclase phenocrysts enclose smaller plagioclase laths and are partially replaced by calcite. Biotite is largely altered to chlorite. A potassium-argon whole-rock determination by Teledyne Isotopes on Sample No. 17 (Plate 84-22A) gave an age of 337±17 Ma. This date should not be much younger than the age of crystallization given the fine-grained nature of the rock which implies that it cooled rapidly below the argon retention temperature.

A separate porphyry dyke (or possibly a set of several dykes) exposed on the trail encircling the hill south of Cheaver Lakes ranges from pale pink to greenish grey when extensively hydrothermally altered (Figure 21). Feldspars in the altered rock

are completely replaced by sercite, and biotite by chlorite. Sulphide mineralization and high scintillometer readings (Table 2) are associated with these altered zones. A rubidium-strontium determination on mineral separates from an altered dyke in drill core gave an age of 278 Ma (Hauseux, 1982). This young age suggests hydrothermal activity locally kept the chemical system open for several million years after crystallization. Drill core confirms that the dykes are chilled against, and are therefore considerably younger than the biotite granite (Unit Dfn_1) and muscovite-bearing granite (Unit Dfn_2).

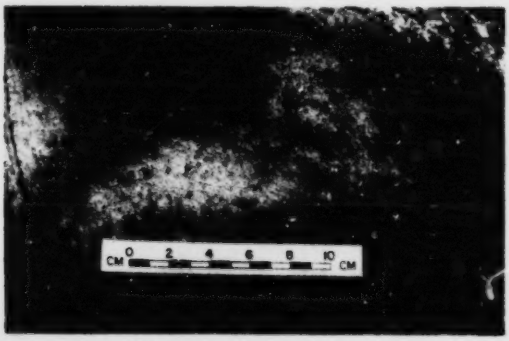

Figure 21. Quartz-feldspar porphyry (Sample Site 15).

ECONOMIC GEOLOGY

Mount Costigan Deposit:

Exploration History: In 1954, Selco Exploration staked the eastern base of the Costigan Mountains on the basis of stream sediment lead-zinc anomalies discovered during a regional geochemical survey. Results of follow-up soil sampling in 1955 and an electromagnetic survey in 1956 were not encouraging and the claims were allowed to lapse (Lock, 1956).

In 1960, Mount Costigan Mines staked the area to investigate the possibility that the geochemical anomalies were transported eastward from the higher part of Costigan Mountains. Soil sampling, geological mapping and a self-potential survey were carried out over the next three years (MacLean, 1963).

International Geochemical Associates conducted a stream geological survey over an area of 250 km^2 in 1969. In late 1969 and early 1970, Silican Mines staked claims to cover base metal and associated silver anomalies centered on Costigan Mountains (Riddell, 1971).

Amoco Petroleum staked the eastern flank of Costigan

TABLE 2

SCINTILLOMETER READINGS*

UNIT	TOTAL COUNT	K+Th+U	Th+U	Th
Dfn_3	240	5.3	2.9	0.8
Dfn_3 **	310-3200	7.6-42.0	3.7-15.0	0.8-1.5
Dfn_2	205-250	5.0	2.4-3.0	0.9-1.0
silicified breccia (Dfn_2)	910	16.0	5.6	0.9
Dfn_1	1o0-220	4.5-6.3	2.5-3.0	0.8-1.3
Dfn_1**	235-290	6.8-8.0	3.0-3.7	1.1-1.4
Dfs	130	4.0	2.0	1.0
Dfr	160-230	6.6-7.6	3.4-4.0	1.3-1.6
Dm	70	2.3	1.0	0.8
Dfv	300	8.0	4.2	1.3
Dfv**	290	9.0	3.3	1.1
€Os	140-180	4.4-6.7	2.5-2.8	1.0-1.2
p€f	180	5.0	2.6	1.2
p€p	140	4.3	2.4	1.3
amphibolite (p€a)	40	1.4	0.9	0.9
granitic gneiss (p€a)	280	10.0	4.4	1.4

*Readings were taken with instrument sitting on outcrop

**Altered outcrops

Mountains in 1973 following a geochemical survey of the Tobique region. The results of magnetometer and electromagnetic surveys were disappointing. However, induced polarization responses were found to coincide with the westward termination of a broad silver-lead-zinc-copper soil anomaly (Maingot, 1974). Between the summer of 1974 and fall of 1976, several holes (NB-T-O-1 to -28) were drilled to test overlapping geophysical and geochemical anomalies (Bjornson, 1975, 1976, 1977). Additional holes were put down in 1979 (TNB-1 to -4).

In 1982, Minerais Lac Ltée conducted electromagnetic, magnetic, and induced polarization surveys on the Amoco property (Lavoie, 1982). The existing core was relogged and claims were staked around the Amoco boundary. Areas where drilling had indicated mineralization were trenched and mapped during the latter part of the summer of 1982 (Crevier, 1983a). Holes LCO-1 to -10 were drilled in the summer of 1983 (Crevier, 1983b, 1984). A further five holes put down in the summer of 1984 have not yet been filed as assessment work.

Geology of the Prospect: The Mount Costigan deposit, located 250 m east of the highest point on the Costigan Mountains, occurs within Devonian felsic volcanic rocks. Geological mapping shows that these volcanic rocks are overlain to the west by sedimentary rocks, and diamond drilling reveals they are underlain by sedimentary rocks to the east (Figure 2; Plate 84-22A).

Mineralization within the 6 to 8 million tonne deposit is concentrated in the core of an east-plunging breccia pipe roughly 200 to 300 m in diameter (Plate 84-28A). Pyrite, sphalerite, galena, and minor chalcopyrite form a stockwork of veinlets and disseminations within silicified vent breccia filling the pipe (Cross-section, Plate 84-28A). Chloritic crystal tuff and lapilli tuff which host the breccia pipe are silicified up to several hundred metres from the vent. Mineralization typically associated with fluorite is common throughout this silicified zone but falls off rapidly in intensity and grade with increasing distance from the pipe. Some of the better ore grades intersected are listed in Table 3.

Long Lake Deposit:

Exploration History: Anthonian Mining Corporation staked the area around Cheaver Lakes in 1955 on the basis of anomalous water samples. Soil sampling and a self-potential survey conducted in 1955-56 outlined favourable targets and twenty holes were drilled (Plate 84-29A). Magnetic, resistivity and electromagnetic surveys carried out in the latter part of 1956 provided additional targets and a further ten holes were completed in 1957 (O'Donnell and Keating, 1957). Two holes were drilled in 1962 (Seigel and Patterson, 1963).

In 1963, Consolidated Mining and Smelting conducted soil sampling and electromagnetic surveys to the southwest and northeast of the Anthonian drilling; three holes (AT-1, -2, -3) were drilled (Shewman, 1964a, b). Mineralization was found to occur along the contact of the North Pole Stream Granite as disseminations and stringers of pyrite, pyrrhotite, sphalerite, chalcopyrite, galena and magnetite in silicified hornfels,

TABLE 3

ORE GRADES, MOUNT COSTIGAN DEPOSIT

HOLE NO.	Zn %	Pb %	Ag (ppm)	Width (m)
NB-T-O-1	2.40	0.65	18.9	0.55
6	6.53	5.11	11.3	1.23
7	3.86	1.10	-	0.91
8	7.88	4.20	15.1	2.13
9	9.24	3.98	15.1	1.52
10	5.72	2.38	6.9	1.52
10	19.00	0.99	-	0.30
11	6.12	2.57	10.3	1.52
12	9.55	4.20	15.1	0.61
13	7.20	4.98	-	1.23
14	6.38	1.20	-	0.30
14	3.75	1.94	-	2.46
15	3.82	2.38	-	1.52
16	3.53	1.99	-	1.52
17	1.44	0.87	-	1.52
21	0.56	0.32	3.4	1.52
22	8.08	4.91	-	0.91
23	0.53	0.33	0.7	1.52
24	1.92	1.00	2.7	1.52
25	8.00	1.44	8.9	1.52
26	2.38	1.26	12.0	1.52
27	1.65	0.12	0.3	1.52
TNB-79-1	1.92	0.58	3.8	1.50
2	5.40	1.81	5.1	1.52
3	14.40	7.87	32.6	1.50
4	3.47	1.75	5.5	1.50
LCO-5	11.20	5.90	15.5	1.50
6	1.91	0.98	1.0	1.50
8	8.55	2.95	13.5	1.50
9	5.80	8.40	28.0	1.50
9	9.45	3.45	7.0	1.50

altered granite veins, and in quartz-feldspar porphyry dykes.

In 1971, Canadian Occidental Petroleum staked claims between Cheaver Lakes and Long Lake to cover base metal anomalies in stream sediments sampled that summer. Cu, Mo, and Ag analyses of soil samples collected in the fall of 1971 revealed the presence of anomalous values on a hill underlain by granite to the south of the Anthonian property (Neelands, 1971). An induced polarization survey was conducted over this area in the summer of 1973 and two holes were drilled (L-1 and L-2) which intersected mineralization associated with pyrite stringers in fractured and silicified granite (Saracoglu, 1974).

Claims were also staked north of the Long Lake group in 1971 between Third Adder Lake and Caribou Lake to cover stream sediment geochemical anomalies (Neelands, 1972). An induced polarization survey located three zones of high response (Glackmeyer, 1973). Two drill holes were completed during the fall and winter of 1973-74. Hole A-1 is located between Caribou Lake and Sears Lake, and A-2 is just east of the map boundary. Stream sediment and water sampling, and a ground scintillometer survey were carried out in 1979 to confirm the presence of uranium anomalies in the area (Robertson, 1980a).

Canadian Occidental restaked the area immediately east of Long Lake in 1979 to investigate anomalous uranium values obtained from analyses in 1978 of the 1971 stream sediment samples. Follow-up stream sediment, water, heavy mineral, soil and rock sampling, ground scintillometer and induced polarization surveys, and analyses of 1971 soil samples for Zn, Pb, and U confirmed the presence of widespread anomalies. Particularly high values of U and Ag were recorded in stream sediments along the shore toward the southeastern end of Long Lake, and high U in water samples coincident with high scintillometer readings were found still farther east along the shore (Robertson, 1980b). Additional claims were staked on the south side of the lake in the summer of 1980.

Geological mapping, trenching, detailed soil sampling, rock sampling, ground scintillometer, magnetometer, induced polarization and electromagnetic surveys were carried out over the area during the spring and summer of 1980. Five holes were drilled in late summer to test geochemical and geophysical anomalies in the northern part of the property (Hauseux, 1980).

The best grades obtained from trenches for the various elements were: 3.12 percent Cu over 0.61 m in trench 15 in the southern part of the property; 3.38 percent Zn over 0.61 m in trench 13 on the south side of Cheaver Lakes; 0.31 percent Pb over 0.61 m in trench 2 just south of hole 80-3; 292 ppm Ag over 0.61 m within the minerals matildite ($AgBiS_2$) and covellite in association with chalcopyrite, arsenopyrite, pyrite, native bismuth and sphalerite in trench 15; 12.0 percent Mo in granite float near trench 11 on the northern shore of Long Lake near its southeastern end, 0.88 percent Mo in granite float on the southern shore halfway along the lake; 3300 ppm U in torbenite-bearing muscovite granite float near trench 11; 1560 ppm, 420 ppm, 8800 ppm, 1360 ppm, and 570 ppm U in silicified granite breccia (Unit Dfn_2), respectively, in trenches 11 and 12 on the northern lake shore, in trench 20 on the southern shore, in

trenches 17 and 8 located about a kilometre north of the lake; and 845 ppm and 3036 ppm U in quartz-feldspar porphyry (Unit Dfn_2) in trench 19 located 1 km north of the lake; 2868 ppm Sn from granite float in trench 4 south of Cheaver Lakes; and 3000 ppb Au in a sulphide vein in trench 15 (Hauseux, 1981a, b; Lipowicz, 1981).

Ten holes were drilled in the central part of the area in 1981 to test induced polarization anomalies outlined that same summer. Six additional trenches were excavated in the vicinity of the drill targets. Highest values obtained for various elements from trench grab samples were: 0.18 percent Cu in trench 25; 3.60 percent Zn, 1.76 percent Pb, and 400 ppm Mo in trench 26; 390 ppm U in trench 27; and 2600 ppb Au in trench 25 (Hauseux, 1981b).

In the winter of 1981, alphameter lake sediment geochemistry, magnetometer, induced polarization, and electromagnetic surveys were conducted over the ice on Long Lake. The location of many of the anomalous alphameter readings suggest radon is entering the lake largely from streams draining the eastern shore of the lake which float has shown to be underlain by silicified granite breccia containing high uranium values (Leonard, 1982). The magnetic low on the southeastern end of the lake (Jagodits, 1982) appears to be associated with this breccia.

Nine holes were drilled along the shore of, and within Long Lake during the winter of 1982. Seven of these tested induced polarization anomalies, one (82-13) searched for the source of U-Mo-bearing float, and the other (82-14) explored a lake bottom sediment goechemical anomaly (Hauseux, 1982).

Grades for some of the better drillhole intersections are listed in Table 4.

Geology of the Prospect: The geological setting of the Long Lake deposit can be summarized as follows. The deposit is associated with a lobe of biotite granite (Unit Dfn_1) extending westward off the North Pole Stream pluton. Base metal mineralization is found in both the granite lobe and sedimentary country rocks as disseminations and stringers of pyrite containing minor sphalerite, chalcopyrite and galena in fractured and silicified host rocks. Mineralization in the sedimentary rocks is concentrated within 600 m of the northern margin of the granite. Veins of granite and dykes of quartz-feldspar porphyry (Unit Dfn_2) intruded into the sedimentary rocks are also commonly enriched in sulphides. Base metal veins within the granite lobe are associated with quartz veining along west-northwest-trending fracture zones (Cross-sections, Plate 84-29A). Quartz-feldspar porphyry dykes emplaced along many of these fractures tend to have mineralization concentrated across the contact between the dyke rock and coarser grained granite host. This suggests that hydrothermal activity related to sulphide deposition was at least in part coeval with dyke emplacement.

Uranium and molybdenum mineralization occurs mainly along the southern margin of the lobe within poorly exposed silicified granite breccia on the southeastern end of Long Lake. The breccia is located on the eastern edge of a medium- to coarse-grained, muscovite-bearing granite stock (Unit Dfn_2). The previously described west-northwest-trending fault zone extending

TABLE 4

ORE GRADES, LONG LAKE DEPOSIT

HOLE NO.	Cu%	Pb%	Zn%	Mo (ppm)	Ag (ppm)	Sn (ppm)	U (ppm)	Au (ppb)	WIDTH (m)
7	1.15				12				0.76
	0.19		1.15		4				1.52
9	1.91								0.76
18	0.28		2.55		20				0.91
24			1.32						0.91
27	0.32		1.20						1.22
AT-1	0.05	0.17	3.73						1.98
L-1	0.04		1.30						3.04
L-2	0.27		0.36						1.67
80-1	0.14	0.14	1.04		52				1.52
	1.88				48				0.30
				260					0.61
80-3		0.20	15.30						0.30
							49		0.46
80-5			1.04						0.15
	0.30	0.18			28			180	0.08
				280					0.30
81-1			9.60		15	112		220	0.30
		0.78	1.00		11				0.30
81-2	1.28		0.28		14	275			0.46
			1.66			152			0.15
81-5	0.19	0.36	5.08			172			0.61
			3.28			161			1.52
81-6		1.92	1.92		18	237			0.15
81-7				540					0.30
	0.39	0.22	1.52		48	526			1.28
	2.72	0.21	0.22		72	160		190	1.14
81-9	4.00				86	1114			0.30
81-10							860		0.30
82-15	2.92	1.64	1.92		64	678		670	0.35
				800			98		0.46
82-16		0.20	1.00						0.09
				200			3440		0.15
				1960					0.30
82-17				1460					2.20

along the axis of Long Lake apparently acted as a channel for the uranium-bearing hydrothermal fluids. Local concentrations of uranium are also found within an altered quartz-feldspar porphyry dyke to the north of the lake where drilling has shown muscovite-bearing granite to be present within 30 m of the surface (Plate 84-29A, hole 81-2).

LITHOGEOCHEMISTRY

Procedures: Representative surface samples of some volcanic and plutonic rocks were chosen for major and trace element analyses. Varieties of granite formed the bulk of the samples as their relationship to mineralization was of particular interest. The analyses were used to classify the granites as to type (White and Chappell, 1983); to quantify chemical variations and differentiation trends between the various granitic phases; to determine if element specialization existed in any of these phases; to compare the chemistry of unmineralized granite with altered, mineralized granite; and to determine depth of emplacement of the granites. Chemical analyses were performed in the Laboratory for Investigations of Minerals at the Technical University of Nova Scotia. Analytical procedures, accuracy, and precision are given in Barr et al. (1982). Results, together with norm calculations, are listed in Table 5; sample locations are shown on Plates 84-22A, 84-28A, and 84-29A.

Volcanic Rocks: Flow-banded felsic volcanic rocks of the Costigan Mountain Formation exposed on the road west of Colters Mountain (Sample No. 1) have a composition of subalkaline rhyolite (Winchester and Floyd, 1977). Lapilli tuff (Sample No. 2), vent breccia (Sample No. 4), and surrounding nonfragmental felsic volcanic rocks (Sample No. 3), all associated with the mineralized zone on Costigan Mountains, possess K_2O to Na_2O ratios indicative of metasomatized rocks (Hughes, 1972). The felsic volcanics (Sample No. 3), host to the breccia pipe, are enriched in SiO_2 if it is assumed that their Al_2O_3 content was originally comparable to that in the flow-banded rhyolite and lapilli tuff (Krauskopf, 1967). These silicified volcanics, together with the contained vent breccia, are also enriched in iron and MgO consistent with their high chlorite contents. Anomalous values of Zn, Pb, S, F and Li occur in the silicified rocks and vent breccia, although visible sulphides were observed only within the breccia. An above normal Cu content is also present in the sample of vent breccia.

Unaltered Granites: The Redstone Mountain Granite (Unit Dfr, Sample Nos. 5, 6) contains lower SiO_2, Be, B, Li, and higher TiO_2, total Fe, CaO, Sr, and Zr relative to the North Pole Stream Granite. The resulting low normative corundum content of the Redstone Mountain Granite is characteristic of an I-type granite, i.e., one derived from an igneous source (White and Chappell, 1983). Such a source is consistent with its association with mafic plutonic rocks and high level emplacement into volcanic rocks of the Costigan Mountain Formation - features typical of compositionally expanded calc-alkaline intrusive suites (Pitcher, 1979).

Unaltered specimens of the North Pole pluton can be distinguished by their light pink colour compared to the greenish

grey colour of altered, generally mineralized samples. Analyses of these fresh samples reveal that all divisions of the western lobe of the pluton extending into the Long Lake area contain over one percent normative corundum and are, therefore, S-type granites, i.e., derived from a sedimentary source. Such granites belong to Pitcher's compositionally restricted series which are generally emplaced at relatively deep levels into high grade metamorphic rocks. This peraluminous nature of the North Pole pluton is reflected mineralogically by the presence of muscovite in Unit Dfn_2 and absence of hornblende from all varieties.

Average normative quartz, orthoclase, and albite percentages for the various unaltered divisions of the North Pole pluton are shown on a ternary phase diagram for the water-saturated, "granitic" system (Figure 22). The biotite granite (Unit Dfn_1, Sample Nos. 10, 11, 12A, 14A), and biotite-muscovite granite (Unit Dfn_2, Sample Nos. 20, 21) of the western lobe plot near the one kilobar cotectic suggesting emplacement at a depth of at least 3.5 km. The biotite granite to the east of the Long Lake area contains less normative quartz (average of 12 samples; Fyffe, 1982b) and may, therefore, represent a deeper exposed level of the pluton. The unaltered specimen of quartz-feldspar porphyry from Long Lake (Unit Dfn_3, Sample No. 17) plots near the 0.5 kbar cotectic and probably intruded within 2 km of the surface. Evidently, over a kilometre of overburden was removed by erosion between the earlier and later intrusive episodes. Previously described radiometric dates suggest these episodes may have been separated in time by as much as 50 million years.

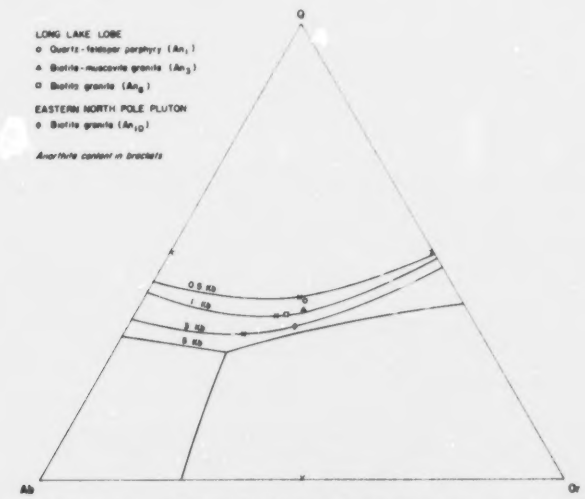

Figure 22. Ternary diagram for normative quartz (Q), albite (Ab) and orthoclase (Or). Minima (x), eutectic and cotectics after Tuttle and Bowen (1958).

TABLE 5

CHEMICAL ANALYSES AND NORMS

	1	2	3	4	5	6	7	8	9	10	11	12A	12B	12C
SiO_2	77.75	77.71	75.38	67.71	70.28	64.95	52.47	47.80	70.61	71.10	71.79	71.96	73.06	72.32
TiO_2	0.15	0.32	0.17	0.02	0.77	0.72	1.77	2.07	0.50	0.38	0.43	0.35	0.28	0.28
Al_2O_3	11.76	11.46	9.70	13.51	14.16	16.89	16.30	16.09	14.06	14.06	14.97	14.98	13.89	14.26
Fe_2O_3	0.75	0.48	0.69	1.90	1.32	1.93	2.02	2.08	0.75	0.53	0.92	0.34	1.37	1.35
FeO	0.20	0.74	1.48	2.63	2.09	1.17	5.60	7.95	1.67	1.51	1.75	1.72	3.22	4.05
MnO	0.00	0.04	0.17	0.23	0.05	0.05	0.13	0.17	0.05	0.07	0.06	0.06	0.16	0.22
MgO	0.09	0.43	3.17	2.58	0.98	0.92	5.61	7.63	0.82	0.60	0.71	0.70	0.54	0.58
CaO	0.15	0.05	0.04	0.00	2.20	3.64	8.96	9.43	1.53	1.14	0.91	1.32	0.89	0.00
H_2O	5.49	8.36	5.36	8.36	3.73	0.70	1.12	0.80	3.76	4.24	4.07	4.33	4.09	4.02
Na_2O	3.07	0.28	0.20	0.18	3.55	6.53	3.59	2.40	3.53	3.58	3.57	3.55	0.17	0.15
H_2O+	0.92	0.08	2.07	2.13	0.25	0.90	1.19	1.54	1.09	1.21	1.36	1.29	2.25	2.83
H_2O-	0.13	0.03	0.26	0.19	0.06	0.19	0.15	0.10	0.10	0.00	0.32	0.24	0.16	0.13
P_2O_5	0.01	0.01	0.06	0.06	0.10	0.14	0.28	0.24	0.10	0.08	0.10	0.08	0.08	0.06
CO_2	0.05	0.12	0.03	0.07	0.02	0.02	0.02	0.02	0.02	0.00	0.10	0.02	0.03	0.02
	100.52	100.01	98.74	99.37	99.58	99.29	98.99	98.32	98.57	98.48	101.06	100.94	99.39	100.25
Be	6.0	3.7	3.2	2.4	3.6	4.4			5.2	5.4	6.4	6.5	5.5	6.5
Ba	1300	540	670	680	690	150			460	430	440	440	180	260
Cu	3	4	4	350	10	9			2	4	15	10	86	31
F	310	380	520	510	460	420			380	290	360	400	690	750
Mo	6	1	1	1	1	0.8			1	1	2	2	7	6
Pb	4	5	320	620	24	6			28	36	20	28	100	282
Rb	198	362	173	279	144	31			119	136	163	197	386	341
S	39	3	6	-	2	1			12	7	5	3	21	65
Sn	6.2	5.7	6.8	6.0	5.9	7.0			6.8	6.9	7.0	7.0	97.0	126.0
Sr	63	25	8	12	200	495			150	120	150	108	7	-
Zn	6	61	245	300	69	35			64	312	98	82	780	135
U	5.8	6.5	6.1	5.7	3.9	6.7			3.3	3.3	6.7	6.5	5.6	6.3
W	4	4	4	4	4	-			4	-	-	4	16	16
Li	1	6	28	12	5	5			17	13	11	10	17	25
Bi	0.05	-	-	0.06	0.06	0.15			0.06	0.06	0.08	0.05	2.70	1.70
Br	155	580	600	380	270	390			115	240	85	75	220	610
B	60	60	200	2180	120	40			100	60	100	50	1200	100
Q	38.66	43.18	49.90	30.29	28.98	16.13	1.99		31.52	30.95	32.11	30.18	55.41	53.93
C	0.52	1.86	3.74	4.39	0.52				1.66	1.72	3.30	2.26	9.49	10.02
Or	32.66	49.56	32.77	50.94	22.23	6.22	6.79	0.99	22.84	25.78	24.25	25.77	24.94	24.44
Ab	26.13	2.37	1.76	1.57	30.27	56.27	31.11	21.01	30.48	31.14	30.42	30.22	1.48	1.30
An	0.68	0.18			10.36	14.98	25.66	31.83	7.12	5.28	3.89	6.06		
Di						1.68	10.43	8.36						
Hm						0.29	4.01	3.75						
En	0.23	1.07	8.19	6.62	2.46	1.56	8.96	12.16	2.10	1.54	1.78	1.75	1.39	1.69
Fs		0.53	2.18	3.42	1.54	0.31	3.95	6.26	1.72	1.05	1.83	2.39	4.25	6.60
Fo								2.54						
Fa								1.46						
Mt	0.14	0.58	1.04	2.27	1.93	2.85	3.00	3.12	1.12	0.79	1.34	0.50	2.05	2.01
Il	0.29	0.61	0.34	0.04	1.47	1.39	3.44	4.07	0.98	0.74	0.82	0.67	0.55	0.55
Hm	0.66													
Ap	0.02	0.02	0.10	0.14	0.23	0.33	0.67	0.58	0.24	0.19	0.23	0.19	0.19	0.16
Po	0.03	0.03	0.06	0.62	0.03				0.03	0.03	0.03	0.03	0.34	0.03

1 Flow-banded rhyolite (Unit Dfv); 2 Felsic lapilli tuff (Unit Dfv); 3 Silicified lapilli tuff (Unit Dfv); 4 Vent breccia containing visible sulphides (Unit Dfv); 5 and 6 Redstone Mountain Granite (Unit Dfr); 7 and 8 Diabase dykes (Unit Dm); 9 Muscovite-biotite granite (local marginal variant of Unit Dfn_1); 10, 11, 12A and 14A Biotite granite (Unit Dfn_1); 12B, 12C, 13, 14B and 15A Altered biotite

13	14A	14B	15A	15B	15C	16A	16B	16C	17	18	19	20	21
74.62	70.00	68.88	76.69	77.60	76.53	77.02	75.92	76.80	76.65	86.67	80.72	74.20	73.67
0.59	0.60	0.63	0.67	0.09	0.09	0.13	0.20	0.15	0.15	0.08	0.20	0.02	0.27
12.57	15.15	14.75	14.76	12.55	12.99	13.08	12.86	13.76	13.32	6.48	10.91	14.52	14.17
1.46	0.31	2.60	2.38	2.83	0.69	1.68	1.05	1.06	0.70	0.83	0.50	0.46	0.61
2.65	2.94	4.62	0.91	0.58	0.74	2.02	3.17	0.24	0.64	0.20	0.47	1.13	0.98
0.12	0.08	0.15	0.02	0.03	0.02	0.34	0.16	0.04	0.05	0.02	0.04	0.03	0.04
0.84	1.00	1.00	0.51	0.13	0.20	0.19	0.19	0.29	0.30	0.17	0.19	0.41	0.44
0.21	1.79	0.16	0.10	0.12	0.08	0.08	0.09	0.10	0.28	0.10	0.11	0.88	0.58
3.67	3.92	3.66	4.66	4.07	5.17	3.87	1.60	5.16	4.91	2.66	4.62	4.84	4.94
0.26	3.16	0.13	0.20	0.19	1.44	0.17	0.11	0.09	3.35	0.17	0.21	3.44	3.24
2.10	1.73	3.20	1.79	1.00	1.66	2.04	2.20	2.17	0.81	1.56	2.00	0.93	1.30
0.10	0.10	0.10	0.10	0.00	0.23	0.00	0.00	0.28	0.09	0.12	0.11	0.00	0.07
0.05	0.16	0.16	0.08	0.06	0.01	0.08	0.06	0.06	0.06	0.06	0.08	0.10	0.08
0.02	0.10	0.02	0.10	0.05	0.07	0.03	0.05	0.05	0.18	0.05	0.03	0.10	0.07
99.03	101.06	99.89	100.77	99.26	100.12	100.73	100.00	100.39	101.27	98.94	100.16	100.96	100.31
1.8	5.7	4.5	5.6	7.1	11.0	6.0	4.1	5.5	6.8	10.0	4.3	5.4	6.6
265	720	415	235	125	170	200	180	180	100	150	290	600	610
120	21	60	70	105	66	99	77	9	3	8	10	6	17
640	420	780	1120	680	300	600	780	600	600	610	960	290	320
5	2	25	6	7	2	6	7	6	1	8	6	1	0.5
26	12	82	10	2	11	360	22	266	18	10	140	22	28
210	159	300	660	420	300	345	347	261	201	186	271	206	214
16	3	11	25	16	9	9	9	12	-	57	69	4	2
90.0	6.0	102.0	86.0	86.0	8.0	72.0	68.0	8.0	6.6	6.0	8.1	7.6	6.0
-	98	5	5	-	19	7	7	8	99	15	14	52	85
1000	230	120	52	29	260	1160	2750	165	96	85	75	58	52
3.2	3.9	5.0	6.6	5.0	8.5	18.5	11.1	26.8	4.9	6.6	9.1	6.2	6.2
12	-	20	8	8	4	-	8	-	-	-	-	-	-
18	17	28	31	18	9	17	22	10	6	52	140	23	25
2.20	0.06	4.20	6.00	3.20	0.08	1.00	1.80	-	-	0.07	0.05	0.06	0.06
180	155	215	340	105	75	60	70	45	75	30	115	100	75
2260	60	2500	60	13300	60	1900	2520	60	120	600	360	20	20
58.18	30.84	51.41	55.62	61.39	67.30	60.70	60.18	57.38	36.97	77.06	62.73	32.73	33.90
8.16	2.86	10.98	9.51	7.85	4.66	8.76	8.88	8.15	2.07	3.32	5.66	2.06	2.62
22.42	23.40	22.40	27.91	26.38	31.15	23.18	21.76	31.12	28.99	16.18	27.88	28.65	29.67
2.27	26.98	1.14	1.71	1.03	16.14	1.86	0.95	0.78	28.29	1.48	1.81	29.13	27.71
0.74	7.90			0.21	0.34		0.19	0.24	1.11	0.28	0.02	1.71	2.43
2.16	2.51	2.58	1.29	0.33	0.51	0.48	0.99	0.74	0.75	0.84	0.48	1.07	1.11
2.14	4.34	6.76			0.69	2.11	4.32		0.40		0.02	1.72	0.92
2.19	0.45	2.80	2.79		1.02	2.39	1.56	0.48	1.01	0.19	0.76	0.67	0.92
0.98	1.15	0.85	0.90		0.17	0.25	0.39	0.29	0.28	0.16	0.39	0.06	0.52
			3.87	1.61				0.73		0.72			
0.12	0.37	0.38	3.19	0.16	0.26	0.19	0.10	0.10	0.09	0.10	0.19	0.23	0.19
0.65		0.71	9.03	3.69		0.53	0.70	0.00	0.03	0.11	0.08		

granite containing visible sulphides (Unit Dfn_1); 15B, 16A and 16B Intensely altered greenish grey quartz-feldspar porphyry (Unit Dfn_3); 15C and 16C Mildly altered light pink quartz-feldspar porphyry (Unit Dfn_3); 17 Fresh, red quartz-feldspar porphyry (Unit Dfn_3); 18 and 19 Silicified granite breccia (Unit Dfn_2); 20 and 21 Biotite-muscovite granite (Unit Dfn_2).

Comparing average chemical analyses of the unaltered biotite granite of the Long Lake area with the unaltered specimen of quartz-feldspar porphyry, shows that the dyke contains more SiO_2, K_2O, Rb, F, and less Fe, TiO_2, Al_2O_3, MgO, CaO, Sr, Ba, and Li. The low Ba to Rb ratio of the porphyry (1.5) compared to the biotite granite (average ratio 3.1) confirms that the dyke is considerably more differentiated as barium, with its higher charge, is captured by early formed potassium-bearing minerals, whereas rubidium tends to be concentrated in the melt (Krauskopf, 1967).

The biotite-muscovite granite has more SiO_2, K_2O, Rb, Li, and less Fe, TiO_2, MnO, MgO, CaO, and Sr than the biotite granite, mainly reflecting the lower biotite and evidently lower anorthite content of plagioclase in the former. Its Ba to Rb ratio (2.0) lies between that of the biotite granite and the porphyry dykes (Figure 23). Although the regular decrease in the Ba to Rb ratio from biotite granite to biotite-muscovite granite through to porphyry is compatible with continuous differentiation of a single magma through time, the Rb to Sr ratio is not. This ratio first increases between the biotite granite (1.4) and biotite-muscovite granite (3.2), but then decreases in the porphyry (2.0). This is consistent with the biotite-muscovite granite being a differentiate of the biotite granite, whereas the porphyry was likely derived by a separate melting event.

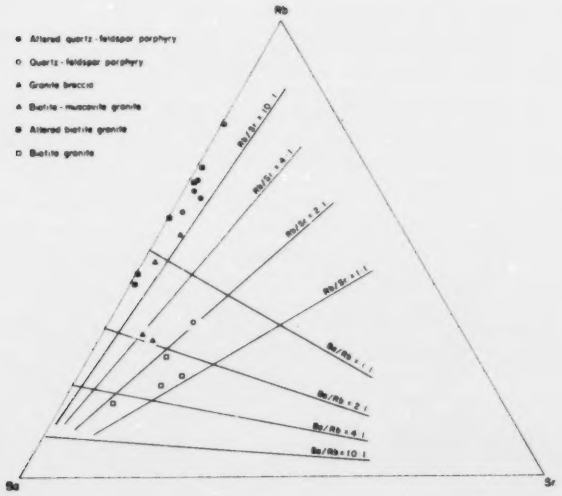

Figure 23. Ternary diagram for rubidium, barium and strontium.

None of the divisions of the North Pole Stream Granite exhibits the extreme specialization (enrichment) in lithophile elements (Rb, Li, F, and Be) that is characteristic of the highly differentiated leucogranites associated with tin, tungsten, and uranium deposits (Strong, 1980). Instead, the pluton more closely resembles those granites that give rise to hydrothermal deposits of the so-called lithochalcophile elements (Pb, Zn, Ag, Sb, Bi, and As).

The Redstone Mountain Granite and various unaltered phases of the North Pole Stream Granite contain Cu, Pb, Mo, and U values typical for an average granite (Krauskopf, 1967). However, the biotite granite and possibly the porphyry (based on a single sample only) of the North Pole pluton are enriched in Zn and Sn compared to 40 ppm and 3 ppm, respectively, in average granite. Since the four unaltered samples of biotite granite all came from areas near mineralization, the anomalous values for Zn and Sn most likely reflect a secondary enrichment of these elements due to a subtle but pervasive hydrothermal enhancement. Alternatively, the western lobe being more differentiated may have magmatically concentrated these elements relative to the bulk of the North Pole Stream Granite. However, neither the zinc nor tin values increase with the degree of differentiation shown by the granite varieties within the western lobe. Zinc, a lithochalcophile element, can be concentrated by release into an aqueous fluid and this appears to be a likely mechanism for producing the abundant zinc in sulphide veins of the Long Lake area. Tin, on the other hand, is a lithophile element that needs to be concentrated in a magmatic melt by extreme differentiation. The lack of specialization in the Long Lake granite would, therefore, account for the absence of economic tin mineralization in the area. Uranium, which occurs only in marginally greater amounts in the North Pole pluton than the average granite (4.8 ppm), also does not appear to increase in the later, more differentiated granites although this would need to be confirmed by further sampling.

Altered Granites: Plagioclase and alkali feldspar in the altered, greenish grey biotite granite (Unit Dfn_1) and quartz-feldspar porphyry (Unit Dfn_3) are completely pseudomorphed by sericite. Biotite is partially to wholly replaced by a mixture of chlorite and muscovite. Altered biotite granite (Sample Nos. 12B, 12C in trench 4; Sample No. 14B in trench 6) has gained H_2O, Rb, Li, F, B, Zr, and lost substantial CaO, Na_2O, Sr and some K_2O and Ba compared to fresh granite (Sample Nos. 12A, 14A) from the same trenches (Plate 84-29A). Such changes are largely the result of hydrolysis of feldspar, whereby hydrogen exchanges with alkalis in the feldspar structure breaking it down to sericite during hydrothermal alteration (Hemley and Jones, 1964). Although Ca, Na, and Sr are removed in solution, K and Ba tend to be fixed in sericite. The excess H_2O, Rb, Li, F, B, and Zr were presumably introduced by the hydrothermal fluids. The higher values of Fe, Cu, Pb, Zn, Mo, Sn, W, Bi, and S are expected due to the mineralized nature of the altered granite, although no tin or tungsten minerals were observed.

The granite breccia (Unit Dfn_2, Sample Nos. 18, 19, contains considerably more SiO_2 compared to analyses of the biotite-muscovite granite (Sample Nos. 20, 21) which tends to mask gains and emphasize losses in other elements if adjustment

to constant Al_2O_3 is not considered (Krauskopf, 1967). When this correction is applied, chemical changes are similar to that for the altered biotite granite except for the large increase in SiO_2, and more notably enhancement in B, Li, Mo, and U.

Specimens of altered quartz-feldspar porphyry from two trenches were analyzed. A pyrite-rich, very fine-grained dyke margin (Sample No. 15B) was sampled at its contact with altered, coarse-grained biotite granite (Sample No. 15A) in trench 5A. Fine-grained, pale pink porphyry (Sample No. 15C) was collected about one metre inward from the dyke contact. Three specimens were taken over a five metre section in trench 17 varying from greenish grey porphyry in the south (Sample No. 16A), near where high scintillometer readings were obtained (total count 3200 c.p.s., Table 2), to pale pink porphyry (Sample No. 16C) in the north (total count 400 c.p.s.). The chemical gains and losses of the altered porphyries compared to the fresh dark pink porphyry far removed from known mineralization (Sample 17) follow a very similar pattern to that for the altered biotite granite described above - the exception being a marked increase in uranium values in the altered dykes. The least altered specimens (Sample Nos. 15C, 16) possess K_2O abundances nearly identical to the fresh porphyry, although their CaO and Na_2O values are much lower. Greater loss of K_2O has occurred in the more altered greenish grey samples. Microscopic examination reveals that alkali feldspar is partially preserved in the less altered samples, and apparently its greater stability is responsible for retention of the pink colouration in these specimens. The similar chemical effects produced largely by the hydrothermal sericitization of feldspar in all three rock types of the North Pole pluton is illustrated for Rb, Ba, and Sr in Figure 23.

SURFICIAL GEOLOGY

QUATERNARY DEPOSITS

In this section, the physical properties of each geologic unit within the map area will be discussed (Figure 24, Plate 84-23A). Mention of the stratigraphic position and the history will be made in discussing each unit, but the overall history of the area will be discussed in a later section. The discussion progresses from the oldest to the youngest deposit: the morainal deposits (basal till and ablation till), the glaciofluvial deposits (ice-contact stratified drift and outwash), the lacustrine deposits and modern organic and alluvial deposits.

Morainal Deposits: Morainal deposits of varying thickness cover more than 90 percent of the area. These deposits have been separated into two units: one consisting primarily of basal till (bT) and another consisting mainly of ablation till (aT).

Basal Till (Unit bT): Morainal deposits consisting mainly of dense compact till have been mapped as basal till. Generally, the surface of this map unit reflects the topography of the underlying bedrock. The till mantle is thickest and primarily found on the stoss side of hills and on flat hilltops.

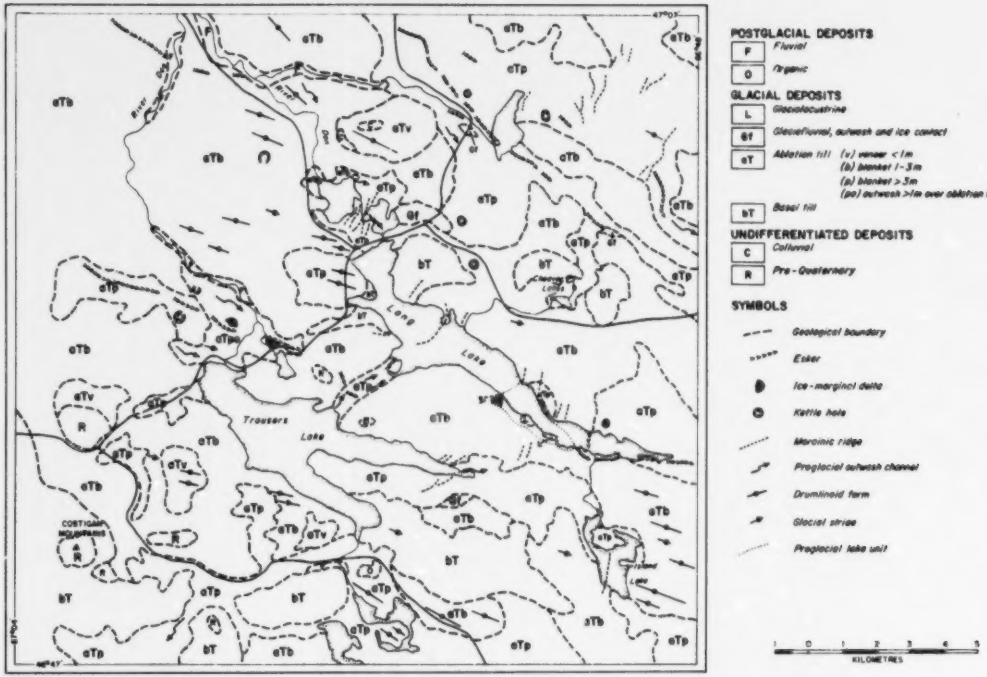

Figure 24. Surficial geology of the Trousers Lake area.

The till has a stoney sandy texture with minor amounts of clay and silt. Its colour is olive-brown (2.5Y 4/4, 5/4, 5/6). Elongated pebbles found in the till usually have a preferred orientation, but stratification is absent. Some pebbles show glacial striae on their surfaces. Basal till is deposited from the base of a glacier through pressure melting and shearing processes.

Ablation Till (Unit aT): Morainal deposits mapped as ablation till result from downwasting of debris-rich glacier ice and are lithologically and texturally similar to basal till deposits but have a higher stone content, a looser structure and contain less silt. The till is typically poorly sorted but locally includes lenses of stratified ice-contact material. Ablation till commonly exceeds 3 m in thickness but occurs principally as a 1 to 3 m thick blanket. Diamond drilling in Long Lake reveals a maximum thickness of 40 m of ablation till (Hauseux, 1982). Where thick, such as in the northeastern part of the area, these deposits are commonly marked by a hummocky or ribbed topography. The colour of the till varies from olive-brown (2.5Y 4/4, 5/4, 5/6) to dark yellowish brown (10YR 3/4, 4/4, 3/6, 4/6).

Glaciofluvial Deposits: Glaciofluvial deposits have been divided into ice-contact stratified sediments (Gf) and outwash sediments (GfO).

Ice-contact Stratified Deposits (Unit Gf): Ice-contact deposits are defined as those sediments deposited by meltwater on or against glacial ice and show internal glaciotectonic deformation (Rampton et al., 1984). They occur in the form of eskers, kames and ice-marginal deltas and consist mainly of coarse and fine gravel (kames and eskers) and sand (ice-marginal deltas).

Eskers are longitudinal ridges formed in tunnels or channels within the glacier ice, whereas kames are mounds formed in isolated crevasses or voids in glacier ice. These deposits are usually more than 5 m thick and sections display cross-bedding and scour and fill structures. Ice-marginal deltas show foreset bedding and are characterized by a decrease in grain size going away from the ice margin.

Outwash Deposits (Units GfO, aTpO): Outwash deposits are defined as those sediments deposited by proglacial meltwater streams, generally devoid of glaciotectonic deformation (Rampton et al., 1984). In the map area, these deposits are generally thin (<1 m) and occur as a discontinuous veneer over ablation till deposits (aTpO). Thicker outwash deposits (GfO) are restricted to narrow valleys. Outwash typically consists of stratified, moderately well sorted, rounded gravel and sand.

Lacustrine Deposits (Unit L): Thin deposits of fine sand and silt have been mapped in the eastern part of Long Lake and have been identified as sediments deposited in a proglacial lake ponded between a retreating ice margin to the northwest and an esker segment to the east.

Organic Deposits (Unit O): The glacially deranged drainage network has created many swampy river valleys where peat, muck and other organic material has accumulated. Some bogs

show peat thickness in excess of 1 m (e.g., around Foot Lake and southeast of Cheaver Lakes).

Alluvial Deposits (Unit F): These deposits consist mainly of coarse gravel, some fine gravel and sand, locally interbedded with organic material. The deposits are the product of postglacial fluvial activity. The sediments are usually 0.5 to 2 m thick. Commonly, small brooks contain minor alluvial deposits that are not shown on the map (e.g., Cronin Brook). Most of the small brooks in the map area have boulder pavements, probably as the result of winnowing of the finer particles by swift glacial streams during the final episodes of deglaciation (e.g., brooks flowing out of Yellow and Cheaver lakes).

Colluvium (Unit C): Mass wasting processes since the area was deglaciated have produced colluvial deposits at the base of most slopes. Many of these deposits are less than 1 m thick, but a few consist of thick accumulations of boulders with gravel and sand. Some deposits are cone-shaped and can be classified as talus fans (e.g., around Clark Mountain, north of Square Lake). Only the significant accumulations of colluvium have been mapped. The texture and composition of colluvium resembles that of the local till.

QUATERNARY HISTORY

Pre-Late Wisconsinan: The present survey yields no evidence of glaciation prior to the latest Wisconsinan stage. Any records of previous glaciations has been eroded away or buried by succeeding ice advances. Laurentide erratics found west of the map area, in the upper Saint John River valley region, suggest eastward movement of Laurentide ice. This glacial movement probably occurred before the Late Wisconsinan, or at the latest, during its early part (Rampton et al., 1984).

Late Wisconsinan: The flow of ice across the map area during the Late Wisconsinan was in an east-southeast direction as recorded by striae, fluted forms and till fabrics (Figure 25). Glaciotectonic features observed east of the area also indicate an easterly direction of ice movement (Appendix I). The observed range in direction (100° to 120°) is attributed to re-equilibration of the ice mass in response to regional deglaciation.

According to Rampton et al. (1984), the main source of ice during the Late Wisconsinan was the North Maine Ice Divide. The relative strength of that regional ice centre was apparently strong enough to prevent the intrusion of Laurentide ice into New Brunswick. Glaciers flowing from the North Maine Ice Divide followed a generally southeasterly trend towards the Bay of Fundy, but in the map area, the flow was diverted along a more easterly course by the regional Gaspereau Ice Centre of central New Brunswick.

The fluted topography observed in the northwest part of the map area is probably associated with the Millville/Dungarvon Phase (Rampton et al., 1984). This phase of deglaciation was characterized by the formation of morainal belts with associated glaciofluvial deposits. Final deglaciation of the region took place during the Plaster Rock Phase with the separation of the

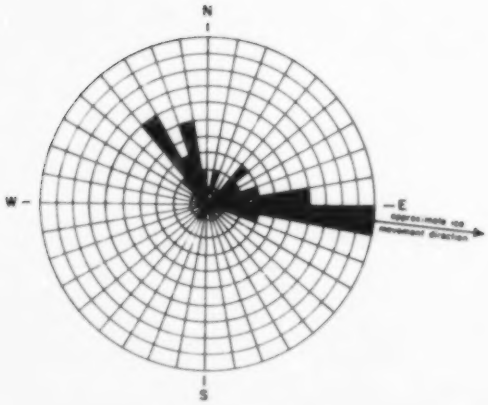

Figure 25. Rose diagram showing pebble orientation. Number of pebbles: 50. Pebble restrictions: length twice their diameter. Location: on west slope of Costigan Mountain, 1.5 km north-northwest of abandoned fire tower.

North Maine Ice Divide into several smaller ice centres.

In the map area, esker systems and morainic ridges mark the gradual retreat of the ice margin. Accumulations of ablation till are commonly thicker than 3 m suggesting that although active, the debris-rich ice was temporarily kept semistationary because of rapid ablation at its margin.

Deglaciation of the map area was accompanied by drainage diversions and the creation of short-lived glacial lakes. The northwest sloping valley of Long Lake was temporarily dammed by a glacier and fine sediments were deposited in the ponded water. Drainage in Trousers Lake was also blocked and for a period of time, waters flowed through the Foot Lake valley where a large esker has been breached.

Holocene: Following the final retreat of the ice from northwestern New Brunswick, the landscape has been modified by the formation of soil profiles, the incision of modern streams and deposition of alluvium and the infilling of wetlands with organic sediments.

TILL ANALYSIS

Surficial Geology as a Prospecting Aid: The tracing of ore boulders is the oldest glacial prospecting method and was applied even before the glacial theory was completely developed (Shilts, 1976). Over the past 10 to 20 years, several detailed studies have been documented (Alley and Slatt, 1976; Vujansuu, 1976).

In order to interpret the geochemical results, an understanding of the surficial geology, particularly of the till stratigraphy and glacial history of the area is necessary. Methods to reach this understanding are surficial mapping, till fabric analyses (Andrews, 1974), till lithology, striation recording, and the interpretation of morphological features.

A basic model of glacial dispersion was given by Hawkes and Webb (1962) and Bradshaw et al. (1980); glacial deposition in general was explained by Boulton (1972). One glacial flow and depositional phase will result in a three-dimensional dispersion fan of anomalous material when an ore body is overridden by the ice (Figure 26). When more phases of ice flow and deposition have taken place, the dispersion will be present in a more complex fashion.

The grain size to be analyzed depends on the target of the survey, the background in the different fractions, and on the cost of the different analytical methods. It is useful to examine earlier, similar projects and their results, before making a decision on these matters (Bolviken and Gleeson, 1979). A one kilometre sample grid is expected to reveal all potential targets. The minus 80 fraction was chosen as the most cost-effective to analyze. Sampling and analytical procedures are given in Appendix II.

Geochemical Results:

Precision and Accuracy: A number of duplicate samples were analyzed to obtain an idea of the reproducibility of the geochemical analyses. The duplicates were split from the same original sample after thorough mixing. It should be noted that some elements such as Au and W show a so-called sparcity effect. The sparcity of particles containing these elements can be the cause of very different results on duplicate samples. For this reason, a single anomalous site for these elements should be looked upon with caution. As can be seen in Table 6, no large discrepancies exist between duplicate samples. The two results are usually approximately the same value, except for W, in which the sparcity effect plays a role.

Anomalies, Threshold, and Background Values: Several definitions of anomalies, background, and threshold values are present in the literature and many attempts are made to give these values a mathematical description (Hawkes and Webb, 1962). In general, an anomaly is any value that differs from the background values (Hawkes and Webb, 1962). The threshold is defined as the upper limit of normal background values, while values higher than this threshold are considered to be significantly anomalous (Levinson, 1974). In this study, the background is chosen equal to the median and the threshold value is equal to

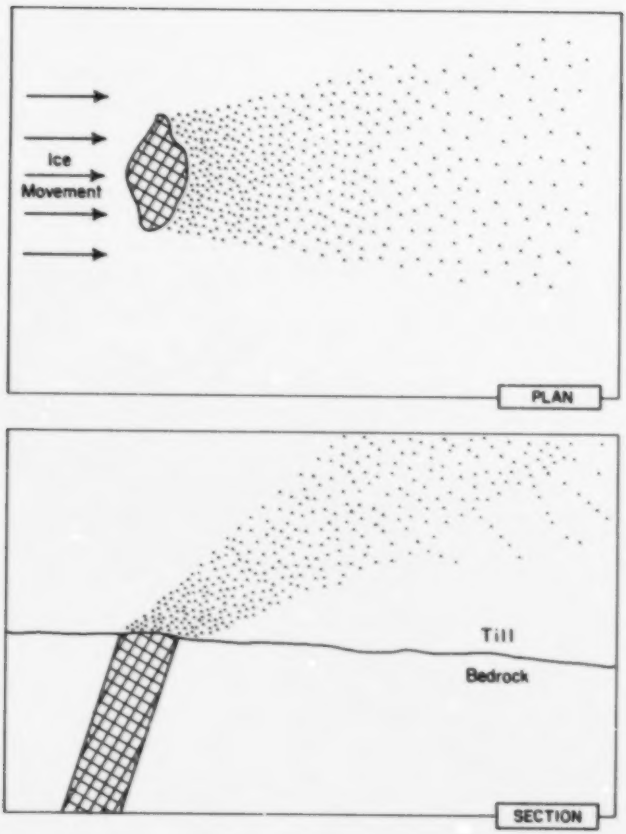

Figure 26. Dispersion pattern of anomalous material in basal till (after Hawkes and Webb, 1962).

the mean plus two standard deviations. Geochemical data and outlined anomalies are shown in Figure 27 (a, b, c) and Plates 84-24A and 84-25A.

Frequency distribution curves for analyzed elements, except those for Mn, Fe, Co, and Au show a significant positive skewness, i.e., values higher than one (Table 7), indicating that many of the values are greater than the mean plus one standard deviation.

TABLE 6

TILL SAMPLE DUPLICATE ANALYSIS*

SAMPLE NO.	Cu	Pb	Zn	Mo	Mn	Fe	Ag	Co	Ni	W	U
B13	11	43	71	<2	150	4.29	1.5	11	21		
	9	39	63	<2	130	4.04	1.5	10	17		
D6	20	22	74	<2	320	3.58	1.5	12	28		
	20	22	76	<2	320	3.56	1.0	11	28		
F14	9	22	20	<2	60	2.62	1.0	5	13		
	8.5	22	18	<2	60	2.57	1.0	5	11		
L5	24	30	82	<2	320	2.97	1.0	20	55		
	24	30	80	<2	320	2.89	1.0	19	53		
P5	28	43	197	<2	620	2.78	1.5	14	23		
	29	43	203	<2	640	2.89	1.5	14	24		
Q12	7	17	33	<2	190	1.64	1.0	8	13		
	7	17	33	<2	180	1.52	1.0	8	12		
S11	8	9	26	<2	130	1.43	0.5	5	7	8	6.0
	8	9	28	<2	140	1.48	0.5	5	7	2	6.4
Z12	14	22	57	<2	270	2.69	1.5	13	32		
	14	22	60	<2	280	2.86	1.5	15	34		
B9										8	
										0	
G10										12	
										8	
H11										8	
										16	
N6										20	
										4	
P6										4	
										4	
B14											4.1
											2.9
D14											2.5
											3.6
G14											1.8
											2.7
L14											3.2
											3.5
N14											3.3
											3.1
Z14											2.7
											1.9

* Values in ppm, except iron which is in percent

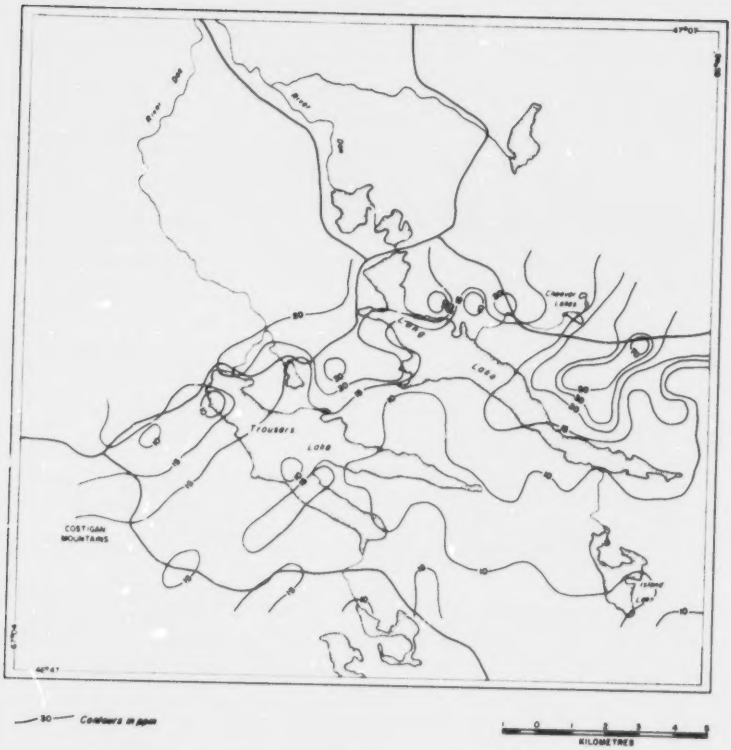

Figure 27a. Till geochemistry values for copper.

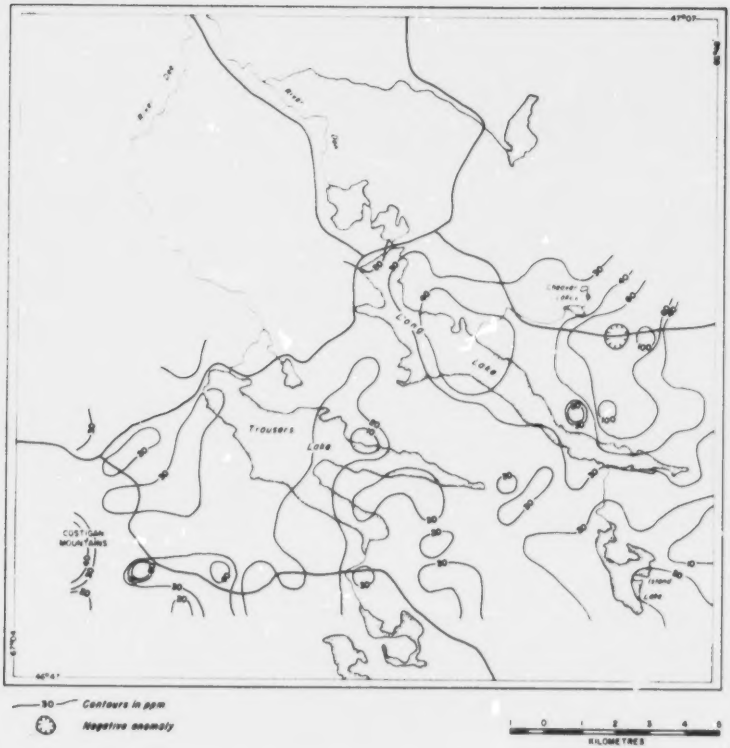

Figure 27b. Till geochemistry values for lead.

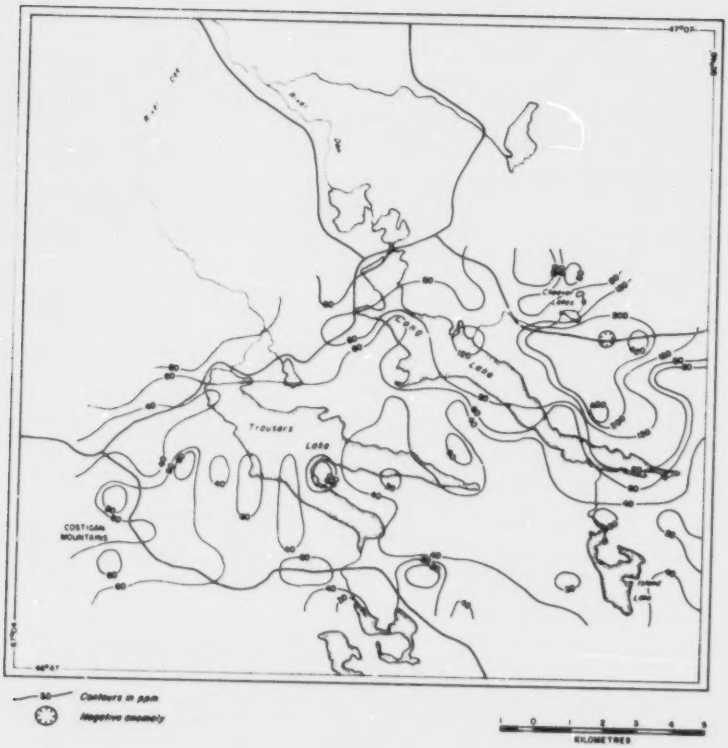

Figure 27c. Till geochemistry values for zinc.

TABLE 7

TILL GEOCHEMISTRY STATISTICS

ELEMENT	MEAN	MED.	MIN.	MAX.	ST.DEV.	VARIANCE	KURT.	SKEWN	THRESHOLD	NO. OF ANOMALOUS SITES
Cu	14.2	12	1	76	9.0	80	16.72	3.42	32.2	6
Pb	28.7	26	9	183	19.3	370	36.36	5.25	67.3	4
Zn	66.1	54	12	515	58.4	3406	27.08	4.47	182.9	8
Mn	234.7	210	40	710	117.5	13804	2.77	1.40	469.7	9
Fe	2.67	2.71	0.71	5.30	0.87	0.77	-0.11	0.28	4.41	6
Co	10.6	10.5	3	22	3.5	12	-0.02	0.48	17.6	6
Ni	21.0	19.5	3	59	11.5	133	0.19	0.80	44.0	8
Ag	1.2	1.0	0.5	3.0	0.4	0.2	2.55	1.06	2.0	12
Mo	2.1	2.0	2	8	0.7	0.4	67.26	8.07	3.5	4
U	3.6	3.2	1.2	9.9	1.7	2.8	1.60	0.95	7.9	10
W	3.2	2	2	24	2.5	6.2	28.33	4.45	8.2	5
Au	0.05	0.05	0.05	0.05	0	0	0.0	0.0	0.15	0

Element values in ppm except iron which is in percent
Median is considered to be background (Hawkes and Webb, 1962)
Kurtosis is the degree of peakedness of a distrubtion relative to a normal distribution
Skewness is the degree of asymmetry of a distribution
Threshold in this study is taken as mean plus two standard deviations

High anomalies for Pb, Zn, Cu, Mn and U are found north of Long Lake, in the area east of Cheaver Lakes. Silver is also anomalous in this area. The Pb, Zn, Cu and Mn anomalies can be related to southeast-trending fracture zones in and along the margin of the medium-grained biotite granite of the North Pole Stream Granite, while the main U anomalies are spatially related to silicified granite breccia and a felsic dyke that intruded this granite. A further U anomaly is present on the south shore of the left hand leg of Trousers Lake. This anomaly seems to be related to another southeast-trending fracture zone.

A negative anomaly for several elements is present in sample P6 of the Cheaver Lakes area. This is probably due to the fact that the sample spot is in the valley of a small brook, which has resulted in retransportation of the material.

The fine-grained, muscovite-biotite granite in the map area has mostly negative anomalies. The Island Lake granodiorite shows a few higher than background values for most elements. Tungsten, cobalt, and nickel show some minor anomalies, whereas anomolous molybdenum was present in only four samples (P7, P8, Q6, and R8), all of which coincide with the base metal anomalies in the Cheaver Lakes area. Molybdenum was detected in two other samples (L8, Z8) but were at threshold values only.

Base metal anomalies east of Costigan Mountains are lower than those to the north of Long Lake in the vicinity of Cheaver Lakes. This may be due to the highly silicified rocks in the Costigan Mountains having a lower weatherability than the granite to the northeast.

Moderate anomalies for Fe, Mn, Pb, Zn, Ag, and U are found east of Costigan Mountains. Silver has its highest values in this area (Plate 84-25A). The mineralization in the Costigan Mountains is present in highly silicified volcanic rocks that would not weather easily. Thus, mineralized particles would likely not be abundant in the fine grain-size that was analyzed and this would be reflected in the lower anomalies in this area. Another reason for the fact that the anomalies are restricted to a very small area and are only moderate might be that the zone of mineralization was one of deposition and not of erosion during glaciation. The mineralization is found on top of the mountains and the thermal regime (see Quaternary History, p. 39) favoured basal till deposition. The mineralization also seems to be mainly present in the middle of four sample spots, which would not promote easy detection. The fact that it was picked up geochemically proves the usefulness of the till sampling method.

All samples analyzed for Au contained less than 0.05 ppm.

Pebble Lithology Study: Fifty pebbles of the greater than ¼ inch fraction were randomly taken from every C-horizon sample and identified lithologically with a hand lens. The nine categories that were differentiated are: old foliated granite, gneissic and amphibolitic rocks, gabbro, felsic volcanics, massive granites, sediments, quartz-feldspar porphyry, chert and quartz, and basalt (Plate 84-26A). The percentages of some lithologies are plotted on small scale maps shown in Figure 28a to c.

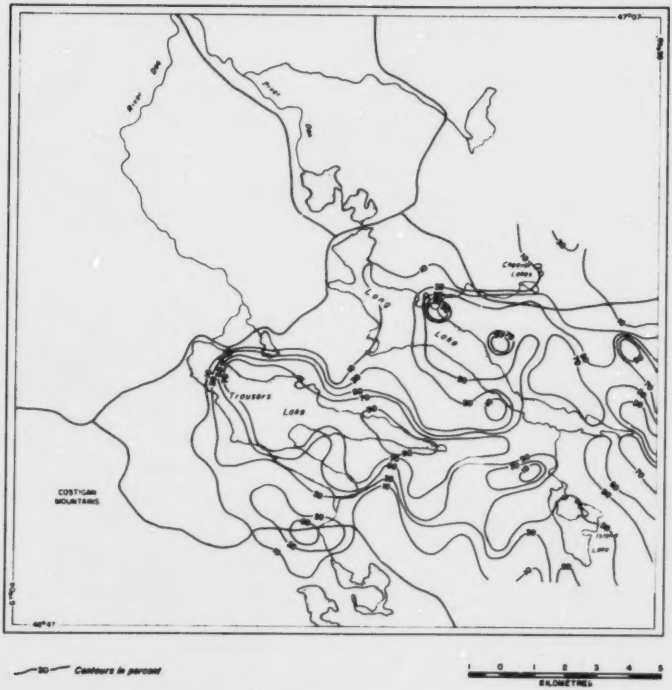

Figure 28a. Distribution of pebble lithologies (Devonian granites and granodiorites in till).

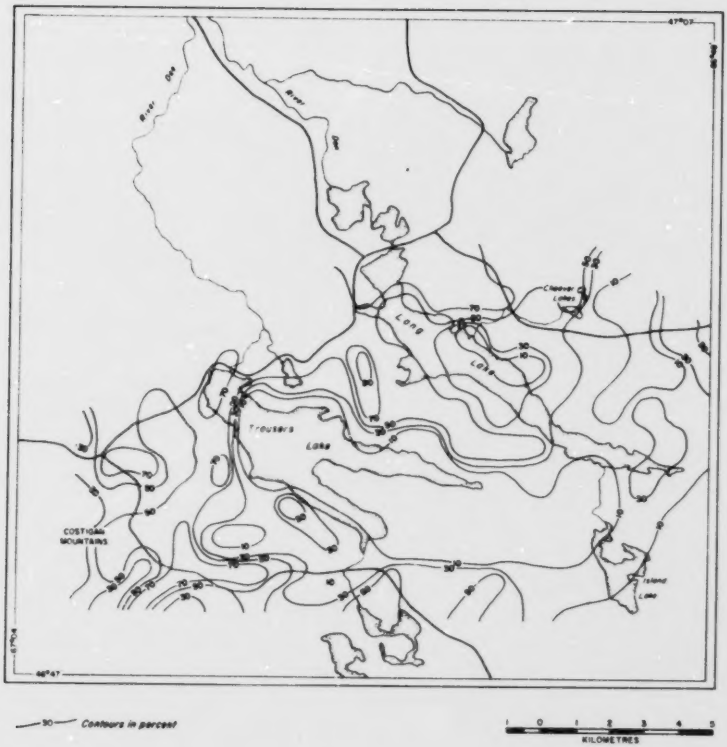

Figure 28L. Distribution of pebble lithologies (sedimentary rocks in till).

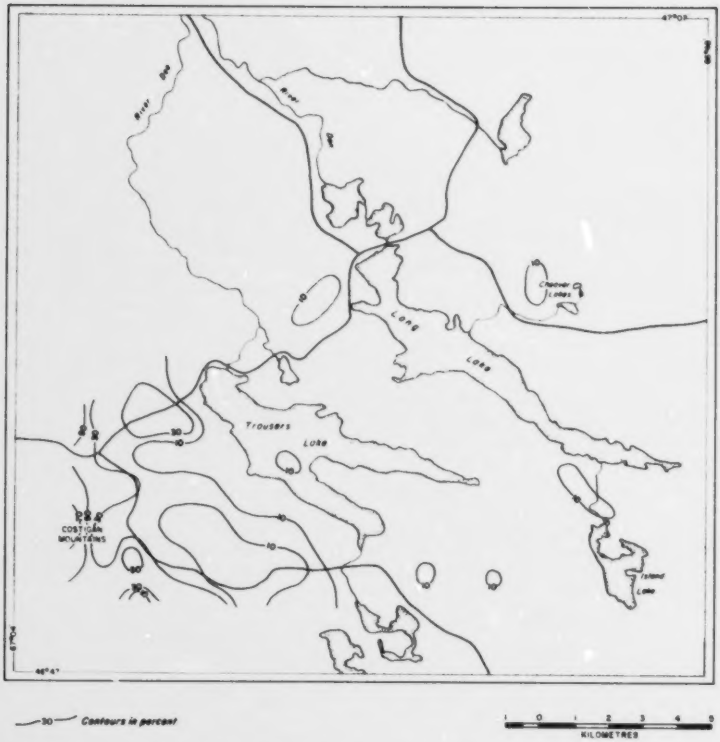

Figure 28c. Distribution of pebble lithologies (Devonian felsic volcanics in till).

One of the problems encountered in the pebble study was the similarity between Devonian quartzose sandstone (Unit Ds) and Cambro-Ordovician sedimentary rocks (Unit €Os). Although they could not be counted separately, it is nevertheless possible to relate their presence to bedrock occurrences of specific age by integrating the other pebble information into their distribution. A similar problem was encountered in the determination of the granites in the pebble fraction. All undeformed granites were classified as one group. In this case, it is also still possible to relate the final data to bedrock occurrences of different granites. Pebbles of coarse-grained North Pole Stream Granite (Unit Dfn_1) and hornblende-bearing Redstone Mountain Granite (Unit Dfr)[1] dominate the areas underlain by these rock types. The medium-grained muscovite-bearing North Pole Stream Granite (Unit Dfn_2) between Long Lake and Trousers Lake, however, does not show up very well in the pebble composition of the till (Figure 28a), although abundant boulders of this lithology are present. The reasons for this appears to be the lower degree of weatherability of the finer granite. The till between the lakes is mainly sandy and contains boulders. Possible weathering along the crystal planes of the abundant coarse-grained granite (Hall, 1983) throughout the area could have supplied the sandy matrix for this till. The result is a very granitic till without granitic pebbles but with granite boulders in the area between the two lakes. Because granite pebbles are scarce, sedimentary pebbles dominate between the lakes (Figure 28b). Their transport direction is roughly 115°.

East of the granites between Long Lake and Trousers Lake, the percentage of sedimentary pebbles increases again after decreasing within the granitic area. The reason for this strictly relative increase is the greater weatherability of granites over some sedimentary rocks during glacial transport, especially where the sedimentary rocks are quartzose.

The old granite (Unit p€f) pebbles that occur outside the bedrock occurrence of this unit, such as just south of Square Lake (Plate 84-26A), are mostly present in places of former meltwater channels and must have been deposited fluvially.

Pebble abundance of a certain lithology increases to a maximum of 1 to 2 km down ice from the bedrock boundary of that lithology, whereas the percentage of pebbles of a particular lithology is constant throughout the area underlain by bedrock of that lithology. Two kilometres down ice of the geological boundary, the pebble abundance of the up-ice unit starts to decrease. The degree of decrease depends mainly on the weatherability of the lithology. A good example of this feature is visible on the pebble distribution map for granite (Figure 28a). The transport distance for pebbles is not necessarily the same as that for the finer particles. Geochemical anomalies, however, should be placed approximately 1 to 2 km up ice to pinpoint their bedrock position.

Some of the pebbles are transported over a larger distance because of their greater resistance. Thus, felsic volcanic pebbles are still present in the till in the eastern part of the area (see Figure 28c), although their bedrock occurrence is some 15 km to the west. Although the Carboniferous redbeds are present only 15 to 20 km to the west, and a 100° to

120° ice flow should have carried the material into the area, no such pebbles were found in the till. This is probably due to the low topographic position of the Carboniferous rocks. West of the map area, these rocks are restricted to the narrow and deeply entrenched Tobique River and were probably not subjected to any significant scouring by easterly moving ice.

As expected, the distribution of boulders seems to be more restricted to their bedrock occurrence. Field notes were compared with the bedrock geology and the highest percentage of boulders of a certain lithology represented the bedrock geology at more than 80 percent of the locations.

A positive correlation of base metal anomalies and the occurrrence of gneissic and amphibolitic pebbles east of Cheaver Lakes seems to be present (Figures 27, 28). Mineralization is presumably localized along the contact of the North Pole Stream Granite within the gneissic country rocks.

In the eastern part of the area, pebbles and stones with a high percentage of sulphides occur in esker sediments. The source area of these sulphide-bearing rocks must not be too far west of the mapped area, as those rocks are not very resistant and transport would abrade them quickly. A possible source is the belt of Devonian felsic volcanic rocks occurring to the northwest of the area.

APPLICATION TO FOREST SITE CLASSIFICATION

Pebble lithology distribution not only gives an indication of direction and distance of glacial transport but can also supply valuable information to forest productivity studies. In the Forest Site Classification system (van Groenewoud and Ruitenberg, 1982), the regolith system, i.e., surficial deposits, together with the climate and geomorphology, is used to evaluate forest productivity. The form and composition of the regolith affect drainage and potential nutrient availability.

The rock and mineral composition of the regolith determines the potential fertility of the soil, because all nutritional elements, except nitrogen, are derived directly or indirectly from the rock fragments. The weathering process of rock particles in soils, and therefore plant nutrient production, is greatly affected by drainage. Good drainage enhances the weathering process, whereas poor drainage impedes it. Drainage conditions are mostly a function of the form and texture of the surficial deposits.

The texture and form of the surficial deposits differs greatly according to their origin and mode of transportation and deposition (e.g., ablation tills are less compact, generally coarser grained, and tend to contain more distal clasts than basal tills). The glacier load changes in composition from the base upward and distance transported (Figure 27). The basal 1 to 3 m of the glacier contains most of the transported material and less than 0.1 percent of this material survives beyond 35 km (Shilts, 1976). Because of the depositional history in the Trousers Lake area, local bedrock formations generally are the source for the greater part of the basal as well as the ablation tills.

Other factors that influence the regolith system are the thickness of the deposit and its topographical position in relation to drainage. However, lithological composition of the deposit is the most important because it determines the texture (Dreimanis and Vagners, 1971), as well as the plant nutrient potential (van Groenewoud and Ruitenberg, 1982). In reality, a till is derived from more than one bedrock formation and this complexity should be considered in the development of a forest site classification system.

A pebble lithology map was produced for the purpose of lithological division of the surficial deposits (Plate 84-26A). The pebble lithology units are dominated by one or several rock types. The boundaries of pebble lithology units tend to coincide with till unit boundaries, topographical features and landform types.

Pebble lithology composition of each unit allows us to make a qualitative evaluation of the available plant nutrients since they are the source of the finer fractions. Till units with a high component of felsic rocks have a high potential for K and P production, whereas till units with mainly mafic components have a high potential for Ca and Mg production. For example, granites and rhyolites are very poor Ca and Mg producers, whereas ultramafic rocks are poor K producers. P has more or less the same abundance in most igneous and volcanic rocks. A combination of both rock types in a till is a potential source for all necessary plant nutrients, except N.

Leaching in soils with alkali feldspars (orthoclase and microcline), plagioclase and Fe-Mg minerals produces K-Na, Ca-Na and Ca-Mg, respectively (Fe is not very relevant as a plant nutrient). A more detailed description of the rock-forming minerals for the bedrock formations in the Trousers Lake area has been given above (see Stratigraphy, p. 5). For example, Devonian felsic volcanics are rich in alkali feldspars, while Devonian mafic volcanics contain plagioclase and Fe-Mg minerals.

Units F, G_1 to G_4, and C_1 to C_3 all have a relatively low Ca-Mg potential, although their K-Na potential is high, whereas unit M will have a low K-Na potential and high Ca-Mg potential. Units FMS and S will have a similar potential for both K and Ca-Mg, although these will be higher for unit FMS than S because Unit S is dominated by sedimentary rocks that consist mainly of quartz, while Unit FMS has high percentages of both felsic and mafic rocks.

In order to make a quantitative evaluation of plant nutrient potential, various sand- and silt-sized till fractions from C-horizon samples were examined under a binocular microscope to determine the relative abundance of different minerals derived from the various source rocks. The samples were dry-sieved using the following Tyler Canadian Standard sieve sizes: 10 (20 mm), 35 (0.5 mm), 120 (0.125 mm) and 230 (0.0625 mm) mesh.

By examining the pebble fraction first and working down to the finer fractions, we are able to relate the fine fraction composition to the pebble composition and thus to the bedrock

sources. The finest two fractions (i.e., all material smaller than 0.125 mm) mainly consist of quartz and are, therefore, relatively sterile, whereas plant nutrients will be stored on clay particles. Because this project initially was not intended to be a forestry-related study, the clay fraction and fine silt was removed by washing in the field. Samples for analysis of exchangeable ions will have to be taken in a later phase of investigation. The fines in ablation till deposits tend to be more enriched in quartz than basal till deposits because the deposition of ablation till is an open system process, whereby the fines are often washed out, as opposed to basal till deposition which is a closed system process (Haldorsen, 1983).

The material smaller than ¼ inch mesh, but larger than 0.5 mm mesh, contains numerous recognizable rock particles, although some rock types start to break down into mineral components for the reasons mentioned above. The fraction smaller than 35 mesh but greater than 120 mesh (0.125-0.5 mm) was chosen to be compared to the pebble lithology, in order to establish the direct relation between the source rocks and the mineralogy of the tills. A small percentage of sediments and felsic volcanics are still recognizable as rock particles in this fraction.

By following this procedure, areas or sites of certain till compositions can be rapidly and accurately delineated. The map with the mineralogy of the 0.125 to 0.5 mm (fine to medium sand) till fraction (Plate 84-27A) shows the contoured quartz values. High quartz percentages are related to felsic volcanics, granites and granodiorite. All other minerals, such as feldspars and mafic minerals are potential sources for plant nutrients. This means that the plant nutrient potential is lower with a high quartz content, although a low quartz content does not necessarily indicate that the potential for all plant nutrients is high because this is also a function of clay content.

SUMMARY

The Trousers Lake area is located across the boundary of two distinct stratigraphic belts. The western belt (Tobique-Chaleur Zone) is underlain by Early Devonian volcanic and sedimentary rocks, whereas the eastern belt (Miramichi Zone) is underlain by possible Precambrian amphibolite, psammite, pelite, granitic gneiss, and Cambro-Ordovician quartzose sandstone and slate. The eastern belt is intruded by granitic plutons of two or perhaps three age groups, i.e., Precambrian(?), Ordovician and Devonian. An elongate Lower Devonian pluton of gabbro and granite (Redstone Mountain Granite) was emplaced into the fault zone separating the two belts.

Zinc, lead, copper and silver mineralization in the area is spatially associated with igneous rocks of Devonian age. At Mount Costigan in the western belt, it is locallized in a breccia pipe within felsic volcanic rocks, whereas that at Long Lake in the eastern belt is related to intrusion of a lobe of North Pole Stream Granite.

Normative mineralogy indicates that this granite lobe,

which consists principally of biotite, and biotite-muscovite granite, was emplaced to within 3 or 4 km of the Early Devonian paleosurface. Over a kilometre of erosion then took place before intrusion of quartz-feldspar porphyry dykes in the Late Devonian. Trace element data is consistent with the biotite-muscovite granite being derived as a water-rich differentiate of the biotite granite but the porphyry dykes appear to have a separate origin. All varieties of the North Pole Stream Granite are peraluminous and hence were probably derived directly or indirectly by partial melting of aluminous sedimentary rocks.

Base metals were apparently concentrated from the granite by release of aqueous fluids and deposited as sulphide veins in fracture systems over an extended period of time. Sericitization of feldspar by the hydrothermal fluids has removed calcium and sodium, and added water to the granite and dyke rocks in the mineralized zones. None of the recognized granitic phases has undergone the degree of differentiation necessary to sufficiently concentrate tin or uranium.

Mineralization at Mount Costigan is closely related in time and space with that at Long Lake. It may be that the same mineralized fluids that were responsible for sulphide deposition at Long Lake escaped via the breccia pipe to a higher level in the crust at Mount Costigan. However, the Redstone Mountain Granite exposed nearest to Mount Costigan and hence a likely source of these fluids, has a meta-aluminous character and is quite distinct from the North Pole Stream Granite.

Late Wisconsinan glacial deposits reach a thickness of up to 40 m in the Long Lake valley. Basal till was deposited by ice flowing east-southeast from the North Maine Ice Divide. Deglaciation of the area occurred during the Millville-Dungarvon and Plaster Rock phases when thick accumulations of ablation till were deposited. Final retreat of the ice was accompanied by drainage diversions and the creation of short lived glacial lakes.

Pebble lithology analyses, combined with other ice movement indicators, provides a model of glacial dispersion that is used to interpret the till chemistry data.

The till lithology study established a basis for forestry researchers to document the relationship between tree growth and till composition. This intergrated study of both bedrock and surficial geology has demonstrated the usefulness of till geochemistry as an exploration technique and should serve as a guide for further mineral exploration programs.

In addition, both the Long Lake and Mount Costigan deposits are evident on the till chemistry maps. The Long Lake anomalies are displaced from their bedrock origin east-southeastward over a distance of 1 to 2 km, whereas the Mount Costigan anomalies are present close to their bedrock origin. This discrepancy between the locations results from differences in depositional environments and bedrock resistance to glacial erosion. Mount Costigan mineralization is located in an area of deposition and is present in highly silicified rocks, whereas the Long Lake mineralization is located in an area of erosion/deposition and is present in highly fractured and weathered bedrock.

Mount Costigan mineralization is also restricted to a small area (less than 1 km^2) and the fact that it was detected demonstrates that a regular 1 km grid is suitable for a survey of this kind.

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APPENDIX I

GLACIOTECTONIC FEATURES NEAR INDIAN LAKE

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Information on the direction of ice movement in central New Brunswick was obtained from the Tuadook Lake area (21 J/15) some 20 km east of Long Lake. Indian Lake, located 5 km north of Tuadook Lake, was the site of a major earthquake on January 9, 1982. Since the United States Nuclear Regulatory Commission was concerned about this unexpected occurrence, the electric power utilities of the northeastern United States contracted Weston Geophysical Corporation to investigate its cause (Northwest Utilities Services, 1984). A trench was excavated 500 m northwest of Indian Lake to expose bedrock in the vicinity of a suspected fault. Excellent glacial features were revealed on the trench walls (Figure 29). The floor and lower walls of the 5 m wide trench show bedrock of fine medium-grained, pink muscovite granite, overlain by highly weathered, coarse-grained grey biotite granite. At one point, these are separated by a fault zone, filled with clay and silicified granite breccia. The overlying reddish brown, uncompacted ablation till has a sandy matrix containing pebbles and boulders. The reddish brown colour is partly the result of soil forming processes. The lower B-horizon boundary coincides with the boundary between basal and ablation till since the ablation till is highly permeable, whereas the basal till is quite impermeable so that soil formation is restricted to the former.

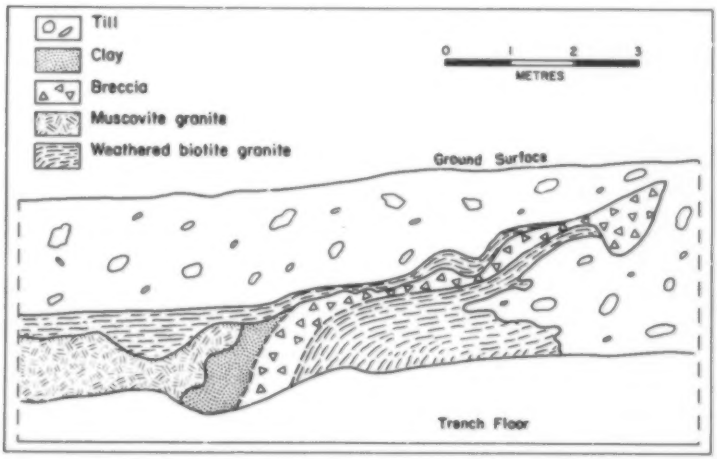

Figure 29. Glacial features in trench (north wall), Tuadook Lake area.

Orientation of elongated pebbles in the basal till shows an ice movement direction between 90° and 100°. Striae and crescentic fractures on the bedrock exposure, 500 m southeast of the trench, show an ice movement direction between 90° and 105°.

The top portion of the weathered granite shows several glacial deformation structures. Aplite dykes, silicified granite breccia and joints are curved to the east which implies a shearing force in that direction. Angular fragments of the dykes can be seen to have been carried along the base of the ice in an easterly direction for about 5 to 6 m and deposited in the basal till.

Bedrock material from the fault zone occurs as a protuberance into the till. The protuberance is surrounded by grey-brown, compact basal till consisting of a sandy matrix with clay, silt, pebbles and some boulders. These boulders are embedded in the bedrock grus at the base of the till. Injection of the bedrock material into the till apparently was caused by glacial shearing, while the till, as well as the weathered granite, was saturated with water at the base of the ice. Similar glacial forms have been described by Catto (1985).

APPENDIX II

TILL SAMPLING AND ANALYTICAL PROCEDURES

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The sample locations were drawn on a regular 1 km grid on 1:20,000 base maps and plotted on 1:20,000 black and white aerial photographs, which were taken into the field. Some of the plotted points were not potential sample spots since they occurred in the middle of lakes. If a point was within 200 m of the lake shore, the sample location was moved from the lake onto the shore.

Sample points close to the lake shores were tied in with recognizable lake shore features and were visited by boat. Other points were tied in to roads, brooks, lakes and other distinguishable features on aerial photographs. Traverses were made from roads or lake shore by pace and compass. On the sample spot location, a hole was dug with a spade into parent material; B- and C-horizon samples were taken at each site. B-horizon samples weighing between 1.5 and 2.5 kg were stored in cotton bags and prepared later in the laboratory. C-horizon samples were taken in 12 litre buckets and sieved and panned in the nearest brook or lake. When the digging of the hole was impossible due to large boulders or hardpan or where there was a lack of parent or B-horizon material, the sample point was moved up to 200 m in any direction in order to obtain suitable material. If a good spot could not be found, the best available material was sampled. If the sample spot happened to be on glaciofluvial or fluvial material the sample spot was also moved in order to obtain the closest till sample. This was done to avoid transport effects in the geochemical data. After the samples were taken, the site was flagged, the site and soil profile described, and the samples carried out to the road or lake. A total of 174 sample spots were collected.

The C-horizon samples were sieved in the field through a ¼ inch mesh screen and pebbles greater than ¼ inch were stored for pebble lithology study. The remaining material was sieved through an 1/8 inch mesh screen in order to obtain the fines. All material between 1/8 inch and 1/2 inch was discarded. The fines were panned to separate the heavy minerals from the light fraction. The heavies with some contained clay were stored in small cotton bags. The retained heavy fraction weighed anywhere between 250 and 1000 g and was air dried at the field camp together with the B-horizon samples. The weight of the sample depended mainly on the water content and the compactness.

In the laboratory, the B-horizon samples were treated in the same way as the C-horizon samples. Gravel, clay and organics were washed out and of the remaining material heavy minerals were concentrated with the gold pan. Both B- and C-horizon samples were oven dried and sieved through an 80 (0.18 mm) mesh sieve; the larger fraction is stored at the Soils and Minerals Building in Fredericton.

The geochemical analyses were performed in the Soils Laboratory of the Mineral Resources Division in Fredericton by Valeria Rinco and Betty Edney. From the B-horizon samples, 1 g was taken and digested in nitric acid (HNO_2) and after boiling, deionized water was added and the solution tested for Cu, Pb, Zn,

Mn, Fe, Ag, Co and Ni on an atomic absorption spectrometer. An additional 0.25 g was taken from the B-horizon samples for colorimetric determination of Mo. The sample was fused with 1 g of a mixture of potassium pyrosulphate ($K_2S_2O_7$) and potassium hydrogen bisulphate ($KHSO_4$), after which it was leached with 5 ml of 6M hydrochloric acid. Two millilitres of this solution were mixed with potassium iodide and dithiol, petroleum spirit was added, tubes were shaken, and the colour of the petroleum was compared with a standard series. From the C-horizon samples, 0.5 g was fused with 2 g of potassium bisulphate and leached with 5 ml of concentrated hydrochloric acid. After adding another 5 ml it was pipetted into a test tube containing 5 mL of stannous chloride solution. After mixing and heating in a boiling water bath for 10 minutes, 1 ml of dithiol solution was added and the solution was mixed and left standing for 10 minutes. One millilitre of isoamyl acetate was added and the solution was shaken for 30 seconds and the results were compared with a standard series made up for the detection of tungsten (Stanton, 1966).

One gram of the B-horizon sample was weighed and put in a plastic tube for detection of uranium by the neutron activation-delayed neutron counting method. One gram of the C-horizon sample was also weighed and put in a plastic tube for the detection of gold using the neutron activation-gamma spectroscopy method. Both sets of samples were sent to Atomic Energy Canada Ltd., Commerical Products Branch in Ottawa, Ontario.

Duplicate samples were taken from the same larger sample for the various analyses. For uranium, 6 out of the 174 samples were sent in duplicate and 5 standard samples were added to the series. Ninety samples were analyzed for Au; no duplicates were sent since they would serve no purpose because of the so-called sparcity effect. For the geochemical atomic absorption analyses in the Soils Laboratory, 8 of the 174 samples were duplicated, and standards for every element were measured after every 10 samples, and results corrected if necessary. The samples were all analyzed in one batch and control over the results was presumably accomplished by the use of laboratory standards and duplicates.

MAPS NOT

FILMED

CARTES

OMISES

POOR
QUALITY
ORIGINAL